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No. 596

RIVETING IN METAL AIRPLANE CONSTRUCTION

By Wilhelm Pleines

PART I

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 596

RIVETING IN METAL AIRPLANE CONSTRUCTION*

By Wilhelm Pleines

PART I

Riveting Methods and Equipment in
German Metal Airplane Construction

Although all constructors in Germany use duralumin quite frequently, and prefer cold riveting exclusively for permanent (nondetachable) connections of individual structural components, their methods and equipment are very diversified. The differences are due to a great extent to the diversity of structural types and to the special shapes of the individual subassemblies. The result is that different manufacturers have developed totally different riveting methods, as well as entirely different working methods.

A. Hand Riveting

I. Riveting of Parts Accessible from Both Sides

Method of operation.— Riveting of pieces accessible from both sides is not difficult because of the comparatively small sizes of the rivets, although it requires in most cases two men, one (unskilled) to hold the dolly, the other (skilled) to drive

*"Nietverfahren im Metallflugzeugbau." From Luftfahrtforschung, Vol. VII, No. 1, April 30, 1930, pp. 1-25.

or clinch the rivet and set the head. The drilled rivet-hole diameter is usually $1/10$ mm larger than the mean body diameter. The rivet is inserted by hand, except in difficult places, where a metal inserter is used (Fig. 1).

This type of riveting is principally resorted to in parts unsuitable for machine riveting due to their particularly unhandy shape or, where machine equipment is lacking.

In drilling holes close to the trailing edge of the wing or the leading edge of ailerons, or for riveting the edges of the metal covering, a drill pattern (Fig. 2) is used, thus obviating marking and center-punching the holes. The divisions on the pattern give the exact distance from the edge, as well as the correct setting and guiding of the drill.

Riveting tools and accessories.— The tools and accessories (of S-M steel) used in hand riveting subassemblies accessible from either side, are shown in Figures 3-7 in their most usual shapes and applications. The shape of the dolly bars themselves, which can be used only for few hard-to-reach rivets, depends wholly on the shape of the piece to be riveted. Elastic dollies are used especially for hard-to-reach places where enormous force would have to be exerted to keep the dolly pressed against the head to prevent it from sliding off. Dollies with knee-plates (Fig. 8) are used where one man can do the riveting. Of course, the piece must be placed low enough so that the riveter can hold the dolly on his knees, as for riveting trailing edges

of ailerons or wings.

By the Rohrbach method, hand riveting is easy because the wing chambers are assembled piece by piece. Here the riveter is able to use a short, heavy dolly on the inside and to press it tight against the surface with a few wooden wedges, so it cannot move.

Of several special rivet joints we mention: that, say, where angle plates are placed between separate sectional beams; at the point where the inserted sheet ends, one of the sectional sheets must be bent, to facilitate further riveting (Fig. 9). But to bend such beams is no easy matter, particularly in duralumin plates and sections, on account of the danger of tearing in the bend. For these reasons, as well as to ensure greater strength, the two flange beams are continued without bending and insertion plates are placed in the rivet rows. In other cases (Rohrbach method) spacing washers are used under the rivets, particularly where a continuous interlayer is not necessary for any strength considerations (Fig. 10).

Faulty riveting and its causes.-- Uniform and straight driving of the rivet body always will be difficult unless the dolly is in the exact center of the body of the rivet. Figure 11 shows the most common kinds of faulty riveting along with their causes.

II. Riveting of Parts Accessible from One Side Only (Junkers)

General Method

1. Tube riveting, rivet inserted from the outside.— When closed sections, such as tubing up to 90 mm (3.54 in.) diameter, and in lengths up to 6 m (19.68 ft.) are used in airplane construction, as in the Junkers type, the riveting methods for such pieces must be considered from an entirely different viewpoint.

Generally speaking, riveting of such structural parts consists in inserting the rivet from the outside, the riveter setting the heading tool on the head and striking the heading tool. The blow is taken up on the inside by the dolly, whose distance from the wall becomes automatically less as the body of the rivet becomes shorter. The closing head is formed on the inside and becomes a flat head (Junkers type).

As to the manner of handling the holding-on tool (dolly bar), developed either stationary as an eccentric tool, or elastic as a spring tool, and the number of men needed, we generally differentiate between a) two-men and b) one-man tube riveting:

a) Two-men tube riveting.— This method requires one man to do the riveting, and another to handle the holding-on tool.

Description of the Most Important Tube-Riveting Sets
for Crew Riveting (two men)

a) Eccentric riveter with rotating dolly (introduced in 1916) (Figs. 12 and 13a).— This tool is the most widely used for two-men tube riveting. The type most commonly used (Fig. 13a) shows two separate blocks, one acting as anvil block (1), and the other as dolly (2). Block (1) remains stationary during riveting, being held firmly in place by its connecting shaft (3) and attached lever (4). Block (2) is flexibly connected to block (1) and acts as eccentric. While riveting, block (2) is turned in the direction of the arrow by means of lever (6) and hollow shaft (5), until the levers (4) and (6) are opposite each other. This action moves block (1), serving as anvil block, up against the riveting spot (direction of straight arrow). The maximum stroke of the tool is controlled by the respective eccentricity of the two blocks. In the type shown in Figure 13b, the anvil block is flat so that the riveting surface of the block lies flat below the body of the rivet. Those shown in Figure 14 are but a preliminary step toward the development of that shown in Figure 13a. In Figure 14a the rivet is clinched by sliding the wedge-shaped dolly lengthwise in the tubing. In Figure 14b the dolly is a block with a spiral surface 1, inside.

Turning the block in the direction of the arrow clinches the body of the rivet. In Figure 14c the originally cylindrical

rotary block has two helical surfaces (1) and (2), whose greatest distance from the riveting place is reduced by turning the block in either direction, corresponding to the clinching. Those shown in Figures 14a, 14b, and 14c are only experimental tools, and their use was discontinued.

Since spars or beams are often very long, very long tools are necessary, and they require large storage space (Figs. 15,16).

Riveting with the eccentric riveter calls for close cooperation of the crew. The block must not be shifted longitudinally during the riveting process. The man handling the tool must turn the eccentric block at even tempo to conform with the even blows, until the handle has reached its end setting (at 180° against the stationary lever). Figure 17 depicts the operations for correct handling. The principal requirement is that the rivet be driven on the stationary block and that the eccentric block be not used as holder-up.

The correct setting of the stationary block under the rivet hole is usually gauged by a marking tool pushed through the respective rivet hole. The man handling the dolly inserts the tool, which is wide open, until the marker touches the stationary block on the side, after which the block is moved a few centimeters ahead until the best place for riveting has been attained. This method of riveting with an eccentric block was first used in the Junkers shops and reached a high stage of development.

β) Rotating eccentric block with double stroke effect (Fig. 18).- One special type, developed within the last few years, merits description. As previously stated, the stroke of the tools, mentioned under α) is quite small, necessitating a different tool for each different tube diameter. But many times the inside tube diameter is smaller at one end than where the riveting is to be done; for instance, at junctions with riveted hinge joints. An ordinary tool, inserted through such a small opening, would not have enough stroke at the place where the riveting is to be done. Here, by simply adding a second plate, a double (eccentric and stroke) action is obtained.

As seen in Figure 18, a second hollow shaft with an adjustable stop block⁽¹⁾ has been placed inside the regular rotating shaft. Moreover, the second shaft (2), is actuated by a handle (3) and, after turning, is fastened by a locking device (4). The adjustable stop block bottoms against the tube wall when inserted through the small opening, and does not increase the diameter of the block. Then, having reached the place where the tube diameter is larger, handle (3) is turned 180°, shifted ahead about 1 x 1 in the shaft, and the block can thus be turned so that it comes below the rotating block. This more than doubles the stroke of the ordinary eccentric riveter, depending on the thickness of the block. Hollow shaft and flap are held fast in the end position by a threaded locking lever, to prevent the block from moving sidewise during riveting. This type of

riveter is used principally for inside tube riveting on the center frame of the A 20 and F 13 type airplanes. At the outer end of the tubular spars are the riveted ball sockets, so that the inside diameter i is much smaller than the diameter of the tubing to be riveted (d) (Fig. 19).

γ) Self-expanding double block riveter with lever (Fig. 20).-

We have already mentioned that the riveting sets described under α) and β) can only be used for one certain inside tube diameter. But since the inside diameters of the tubular spars of Junkers type vary continuously - tapering toward the wing tips - several kinds must be in readiness for the different diameters. The tool described here can be used for different inside tube diameters, but gives best results in tubes having 60-millimeter diameter and over, on account of its light weight for the smaller diameters. The anvil block consists of two identical half-round cheeks or blocks, with two compression springs between, holding them apart. When inserting the tool in the tubing the springs and the two cheeks are pressed together by a rope and lever, then, having reached the place of riveting, the rope is released, the blocks spread out and bottom against the walls. Hammering on the rivet head vibrates the dolly on the inside, and the rebound of the blocks drives the rivet.

δ) Automatic-spreading riveter with roller (Fig. 21).- This is like the one described under γ) but instead of the lever, a pulley or roller is used.

ε) Sliding eccentric riveter with tongs (Fig. 22).- This is used more for riveting oval spar sections, such as aileron spars, C-sections, etc. This tool consists of two half-round blocks connected by levers (1) and (2). The upper lever (2) is joined to a pair of tongs by means of a guide rod. One arm of these tongs (3) can be lifted 90° . By this operation the upper block (4), which acts as anvil block, is brought close to the riveting hole. This riveter's advantage is, that it has greater stroke than any other kind; its disadvantages are, that it takes two men to operate it, it takes up much space if used for long tubing, and it is too expensive to manufacture.

ζ) The self-expanding riveter with one pressure bar.- This has a spring on the inside which pushes a foot-like pressure bar (Fig. 24) down and outward. This bar is held in two sliding tracks with two corresponding guides and pushes the foot-like part downward. When slipped in a tubing, the compression spring is released so that the pressure block, formed within the cylindrical body as anvil block, can be pushed in. As soon as the rope is released the spring pushes the pressure bar out, so that the block always bottoms against the wall, and acts as an elastic anvil block without having to change the stroke setting from the outside by a second man. The second man simply inserts the tool in the tubing and pushes the riveter forward, taking care that the riveting set does not tip over, by holding the guide rod lever. The advantages are: stroke setting large

and automatic; disadvantages - too expensive and requires two men to operate it.

η) Self-expanding riveter with double foot-control.- with double compression spring for riveting long pieces without changing the position of the riveting set.- The different size foot-plates of both pressure bars can be exchanged, thus making it possible to use this tool for still larger tube diameters.

θ) Riveter with pressure bar, operated by tongs.- This is similar to those already described, but the self-acting spring has been eliminated. The pressure bars are actuated by lever and tongs, the stroke changes being effected by the man-handling of the dolly bar. The drawback of this device, aside from the mechanical stroke change, lies in the necessity for using a second man continuously, while with the other types this man can be spared temporarily. The guide tube is fastened outside, so that one man can take care of several sets simultaneously.

b) One-man tube riveting.- Although this problem has not been solved completely, it nevertheless results in a decidedly lower cost (about 25%, instead of 50%) because the dolly can be operated by unskilled, hence cheaper, labor.

Summarizing the advantages of one-man riveting sets, we find:

- 1) Lower manufacturing costs due to elimination of one man, and consequently, lower labor cost for riveting (about 25%), and 50% in time saved;
- 2) Saving in scaffolding and space due to elimination of second man (Fig. 23);
- 3) Elimination of insertion rods and their necessary equipment for handling and holding.

We follow with a short description of some of the most important riveting sets at this stage of development.

a) Riveting set with Bowden cable and guiding tube (Fig. 24).—

The tool is inserted by guiding tube (1) into the tubing. The guiding tube rests between two cheeks or blocks in such a manner as to preclude tipping over of the tool while riveting. The cable enables the riveter to move the tool to any desired place without leaving his place to insert the tool. Moreover, the cable end outside of the tubular spar shows the riveter the exact position of the tool.

The stroke is controlled by Bowden cable and foot lever where the riveter is stationed. The advantages of this type are remarkable; the riveter himself, familiar with the whole riveting process, lifts the dolly by touch, by a gradual pressure on the foot lever as the clinching progresses. But the manufacturing costs are prohibitive. In fact, in comparison to the eccentric

type, they are about ten times as high.

β) Self-acting two-block riveting set with flat spring, adjusting curve and guide strips.- This consists of two semi-cylindrical blocks and a leaf spring laid flat and fastened to the lower block. The upper block runs in vertical guides to prevent the tool from falling to pieces when removed. The tool is operated by ropes.

Originally this type was made without adjusting curve and guide strips, but it became difficult to judge whether or not the tool turned when pulling it through a metal spar or whether it was held by other rivets. To overcome this, spiral guide surfaces, symmetrical to its longitudinal axis, were attached on the upper side of the riveting tool, so as to bring the body of the dolly with its symmetrical plane through a mandrel inserted from the outside below the respective rivet hole. It simply required putting a scriber into the rivet hole; by pulling the tool past, the scriber follows the spiral guides and sets the tool for the correct position. (Fig. 28.)

γ) Self-acting two-block riveter with tension spring and sliding wedges. (Fig. 25.)- Here the dolly is identical to the one described under β, but the leaf spring action being insufficient, a tension spring was installed longitudinally between the two blocks, the tension of which tends to bring the two wedges closer together. Owing to this wedge action the upper block (anvil block) is pressed against the metal tubing. The

same advantages and drawbacks enumerated under β , apply to this type. Both can be used for two diameters, i.e., below 60 mm.

6) Self-acting one-point riveter with tension spring and sliding wedges.— This was contemplated as an experimental type to avoid the many occurrences of inability to turn the tool inside of a tubing, whether due to other rivets or too much spring action. A guide ring was elastically set into the tool around the rivet place so that, because of the spring tension, the rim of the guide ring on the sides of the tubing was pressed tight around the rivet hole, and so that the rivet shank within the guide ring could be clinched on the fixed anvil block.

c) Self-acting triple-block riveter with elastic cones and tension spring (Fig. 26).— Mounting a tension spring on the inside of the riveting tool increased the difficulties of mass distribution, so it was attempted to attach the tension spring on the outside of the blocks serving as anvil block and counterblock. Since, in addition, three sector-like counter-supporting blocks had been provided to be held together by short springs, it became difficult in itself to install a spring on the inside. The result was a compression spring on the outside which tends to bring the two side cones (k) closer together, and which spreads the three blocks apart through the produced wedge action. Subsequently, however, the cones were replaced by flat pieces because they got out of line and thus prevented uniform spreading of the three blocks.

ζ) Self-acting three-block riveter with spiral (Fig. 27).-

In contrast to the preceding type (ε) the longitudinal edges of the sector-like blocks, held by radial springs, are helical to prevent the tool from turning while in use. The three-block type was made for tube diameters over 60 mm, and the two-block type for diameters over 45 mm.

η) Self-acting two-block type with guide surfaces (Fig. 28).-

This type comprised two blocks, the larger, heavier block (4) as anvil, the smaller (13) as holder-up or backing tool. Both blocks are spread apart by vertical spiral compression springs and perpendicular guide pins. This tool was developed because the longitudinal springs of the tools described previously did not allow smooth operation, or were at least inferior to the type with vertical springs. One advantage in contrast to the older types is the ground-off edges at both ends which avoid catching on other rivets.

Its advantages are that it can be used for two tube diameters, and it is easily exchangeable; its disadvantages are that it is too expensive to manufacture and it is hard to pull horizontally. The tool has proved satisfactory and makes up for its high cost of manufacture by its interchangeability. It is used especially with a solid guide rod and adjusting device for riveting tubular spar joints. (See Fig. 29.) The solid guide rod can be held in a vise and the tubing to be riveted is slid over it giving a solid support.

In connection with this tool we shall mention yet another similar to it which, in contrast to all tools described hitherto, is not to act as elastic anvil but as fixed counterblock for one-point riveting. The basic idea was to form the counter-support invariable in its height while the sheet metal tubing was to be elastically compressible while driving the rivet. In drawn tubing this method would prove unsatisfactory on account of the stresses appearing in such tubes, but it is feasible where metal sheets are bent and riveted as tubes.

4) Riveting set with one-piece elastic anvil block.— The tendency in the development of simple tools has been to produce a tool such as is here described. It consists of an iron core serving as anvil block pressed by springs against the tube walls. Accordingly, the counter-supporting or bucking-up block is equipped on its entire periphery with elastic bodies so that it is at a slight distance from the walls and makes riveting possible on all sides of the tubing without twisting. At first the elastic bodies consisted of compression rubber which were subsequently exchanged for cylindrical springs arranged radially in the iron core, with knobs or balls on the outside to ensure uninterrupted movement in the tubing, (the balls are held in sleeves). The extraordinary simplicity and handling of these tools is surprising.

Naturally the spring action had to be light enough so that the rivet could be inserted. The length of the tool ranged

between 300 and 400 mm, the ropes enabled shifting to the sides. To avoid unnecessary turning of the tool and make easy handling of the rope possible, the latter was run over rollers such as had been done previously and which proved quite satisfactory. The stroke is small so that a different tool is necessary for every different tube diameter.

Since the wing spar flanges consist of tubes of different diameters tapering toward the trailing edge, there was likewise a possibility of bringing all riveting tools needed for this inside riveting into the spar at one time (about 5 for a spar), regardless of the different sizes - in the right sequence, of course, and shift them as needed by the individual ropes. This method has proved satisfactory. To prevent the tool from shifting in a tubing it has lately been attempted to extend the spring-equipped iron core so as to reach over the entire length of the tubing. Experiments with it ranged from 1.5 to 2 m lengths and tube diameters below 50 mm. The first model had a completely round section (Fig. 30a). Subsequently, however, it was flattened longitudinally so that this flattened surface could be adjusted below the rivet hole (Fig. 30 a - c). The results were so gratifying that it has been decided to use it for riveting the wing spars of the F 13 and A 20 types of airplanes. This concludes the enumeration of one-man riveting sets, but there are still certain features which merit special notation.

a) Stroke.- It is very important that tube diameter and tool diameter correspond because rivet length and tool diameter must balance exactly. If the tool diameter is too small the rivet head becomes too high. If the rivet shanks are too long they are apt to slip, the rivets are driven crooked or clinch at the regular head instead of at the second or closing head.

b) Weight of Riveting Set.- Another stipulation is that clinching tool and dolly harmonize in weight. Many tools being too light for heavier rivets (over 4 mm diameter) were loaded with lead, but the wear on the hammering surface calls for hard metal (case-hardened boiler tubing).

c) Movement Inside of Tubing.- The riveting tool must be shaped so that it can be shifted freely without catching on any rivets,- hence the cone shaped ends of the blocks and the conical end sleeves connected with the rope. The rope itself must not be too heavy.

d) Setting of Tool.- It is important to keep the tool from turning inside the tubing as well as to make it possible for the riveter to set the tool at the right rivet row.

e) Operation of Tool.- Most riveting methods require two men,- the riveter, and his helper who has to 1) shift the dolly from one rivet hole to the next, and 2) adjust the counterblock of the dolly during clinching and head making, which means that both men must work close hand in hand. Shifting and adjusting the counterblock from where the riveter stands has the advantage that he is

dependent on himself only and can gauge the motions of the counter-block to fit the force and number of his hammer blows.

f) The Foot-lever Operated Counterblocks,--(Fig. 31a),--as attempted by the Junkers company, is a rope operated riveting tool with outside rivet insertion. The dolly (2) can be shifted arbitrarily from the end of the tubing (1) by means of a hollow rod (3). The correct spacing in height of the counter-block (5) carried in the dolly (2) is accomplished by the wedge action of part (4) whose upper part is equipped with slanting wedge-shaped surfaces. Moving part (4) to the right, by means of guide rod (6) in the hollow shaft (3), counter-block (5) slowly moves upward while the rivet is driven. To produce this movement a band (7) of guide rod (6) is loaded by spring (8) supported in the head piece (9) of hollow bar (3). Guide rod (6) is connected to a rope (10) leading outside over pulley (11) and passing through flexible tubing (12) reaching bottom plate (13) of foot treadle (14). The control rope is fastened to guide lever (15) hinged to foot treadle (14) and shifts to the left when depressing bottom plate (13). Movement of dolly (2) from one rivet hole to the next is accomplished by pushing hollow bar (3) forward which must be done by a helper. But the correct handling of block (5), which requires exact knowledge of riveting procedure, is left to the riveter.

Figure 31b is somewhat similar to Figure 31a. The wedge-shaped dolly (2) and counterblock (5) are rod connected,-- adjusting bar (3) to block (5) and control rod (6) to dolly (2),-- so that block (5) makes the required cross movement. At headpiece (9) of adjusting rod (3) we again see a lever (11) which serves to reverse the movement of control rod (6). A support roller (18) obviates holding the free rod ends. Frame (13) is connected with (11) by a fixed rod (21) so that the riveter when shifting (13) simultaneously moves the dolly. Frame (13) is equipped with rollers (23); a fixed pointer (22) shows the exact location of the dolly from the outside. The foot lever is operated by depressing (14), and through rod (24), crank lever (25) and rod (26) moves lever (11) so that block (5) assumes its correct position.

2. Tube riveting with inside insertion of rivet.-- There always has been a tendency to develop a tool which would make it possible to head the rivet from the outside, as attempted by the Junkers company, and which would allow simultaneous insertion of many rivets and their subsequent placing from the inside in the respective rivet holes without changing the riveting tool. According to the Junkers Patent Specifications it comprises a freely movable body, carrying within a chamber containing a series of rivets a device for pushing said rivets forward in the chamber, and a mechanism for moving the rivet counterblock which serves for the insertion of the rivet into the rivet hole. This

body is, on account of its great mass inertia, suited to act as dolly for heading rivets from the outside, thus making outside support of the piece at the rivet hole superfluous. By means of a long rod or sleeve, which at the end of the piece is suitably carried in a socket and interlockable, the dolly is brought to the respective place of riveting. The aforesaid devices, likewise mounted inside of the body, which serve for pushing the rivets forward for the insertion of rivets into their respective rivet holes, adjustment of counterblock, etc., are controlled by lengthwise or rotating transmission links which likewise are handled from the outside from the sleeve fastened to the plate to be riveted. Further improvements made on this sleeve make it possible to bring the rivet always exactly below the rivet hole, thus facilitating and accelerating the insertion of the rivet.

3. Riveting of tube splices and tube joints.— Most tubular spar joints and splices are riveted by the one-man method. The riveting tool is clamped in a vise, the spars are pulled over the tool and the riveting is done from the outside. The correct setting of the tool is accomplished on the outside by the free guide arm of the tool,— the elastic double-block riveting set (Fig. 29) is frequently used,— or by a marking needle. The different types of tubular joints and splices can be seen from Figures 32 to 38.

According to strength tests made by the Junkers company on such test specimens, there is no reason to be apprehensive of

lower buckling strength in spliced tubing than in one-piece tubing. In nearly all breaks the fracture occurred away from the splice. In splicing large size tubing the joints have 5 - 6 rivet rows, in smaller ones, 4 rows. In splicing tubes of different diameters the ends to be riveted are flattened and shaped multiangular according to the number of rivet rows. (See Figs. 32 and 33.) In butt joints of tubes with the same diameter the butt plate is similar to lap riveting but shaped alike on both sides. (See Fig. 35.) If two tubes join flush but at a certain angle, the butt plates are cut out on the outside in special cases, as shown in Figure 34.

On some special parts, such as on the fuselage junction points of the A 31, the ends of the tubing must be cut off in order to fasten this structural component to the fuselage longerons by gussets and, if possible, by rivets. For that reason the tube ends were slit on the sides and then reinforced by riveted fish plates, as shown in Figure 39. The extension of the fish plates beyond the tube end is sometimes used for attaching to the fuselage longeron.

4. Riveting of ball joints.— The ball joints at the ends of the spar flanges of the T_z pieces are generally iron riveted, inserted from the inside and driven on the outside with a round head. This type of riveting does not wholly fall within the scope of inside riveting where the inside insertion is very difficult and at times totally impossible. It is always possible

to insert the rivet from the inside wherever ball joints are riveted in. With the use of iron rivets in ball bearing joints it becomes difficult with the small tube diameter to bring any heavy dolly on the inside, the more so since the connecting flange of the ball joint which is riveted on further decreases the inside diameter. (See Fig. 40, a, b showing new type of ball bearing joint.)

Based upon extensive experiments, the dolly, shown in Figure 41, was then developed. The tool bottoms at (A) against the inside wall of the tubing, the riveting is done at (N), and at (H) the counterblock is supported by (A) by pressing the free lever arm upward. (A helper does this from the outside.) The mass of the tool is outside at (M). This tool has proved quite satisfactory, to the exclusion of nearly all others. The counterpressure from the outside must not be relaxed so that it becomes quite tiresome. Of course it takes two men to operate this tool. From experiments to convert this type to a one-man set, a self-expanding riveter for ball-joint connections was developed. It is somewhat like those outlined in a, n and s. A lever adjustable to 90° , running in a notched pawl, releases the spring compressed by the rope and through the released spring tension the pressure bar with its foot treadle moves outward.

5. Riveting panel points for joining Z-struts.— The junction pieces are riveted with iron rivets on the weld-iron flanges, and the riveting tools used for this operation have already been

described, including those under b, and II, a. The riveting of these junctions requires great care and very thorough check.

As may be seen from Figure 42, the tubular spars were formed by half-round flaps (c) or by flattening the ends (a) and (b). (See Figs. 37, 38, 43 and 44.)

6. Riveting of metal sheets for tubing.- Of late the use of drawn tubing for front spars of wings and ailerons has been discontinued and metal strips, previously bent on a bending machine, are favored. One advantage, in contrast to a drawn tube, is that it is possible to make conical tubes as well. In addition it permits the use of larger size and thin-walled tubing. The manufacturing costs are said to be lower than for drawn tubing. Method and mode of application are patented by the Junkers company.

The tool used is an iron pipe which is slipped into the bent metal strip and whose outside diameter is a few millimeters smaller than the inside diameter of the tubing to be riveted. The rivet rows are single, alternating with double rows (staggered). The edges of the plate are scarf riveted. In splicing such tubes it should be remembered that the joining tubes are spliced with staggered rivet rows so that they, as well as the scarfed metal strips, do not lap (Fig. 45). Another point to be noted is that the rivet rows must not coincide with those of the metal skin. (See Fig. 46 for right and wrong spar setting.)

III. Water- and Pressure-Tight Riveting (Floats, Tanks, etc.).

Water-tight riveting, as used in floats and hull structures, requires great care and expert handling on the part of the riveter, especially when riveting thin metal sheets. As tightening material commonly used, we have 1) muslin for outer skin, and 2) ticking (twill) for keels and bulkheads. These materials are impregnated on both sides with red lead placed in small strips between the seams and the sheets are then riveted as usual. The rivets are seldom calked, but great care is taken in forming the head so that it fits up tight all around. No more packing than can be used in a day should be prepared because red lead becomes hard in time and the joints are not carefully filled out. One drawback of red lead is the added weight increase, although it is not advisable to resort to calking on account of the fact that the metal plates used are thin and apt to be damaged.

Recently I saw a tool in Fürth, which is used for float construction. Here the heading tool can be used simultaneously as riveting set (Fig. 47).

Waterproof and pressure tests must not be made before the packing material is absolutely dry; neither is it advisable to tap the seam after riveting.

In riveting fuel tanks, where galvanized copper rivets are usually used, the conditions are similar. The riveting is exclusively done by hand. The use of packing material, such as in float construction, is dispensed with as a rule because the

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rivet heads are in most cases soldered over on the outside. It is hardly possible to prevent the thin plate from denting around the second head, but this really is of advantage here since it makes the soldering of the second head easier. Lately it was attempted to overcome one cause of tank leakage by a method indicated in Figure 48. In riveting tanks, particularly wing tanks, it often happened that they sprung a leak, due to continuous concussions of the metal plate, which became evident in a tear around the rivet head. So recently special reinforcing strips were placed around the tank seams to the height of the inside reinforcements. In addition washers were placed under the rivet heads and the whole finally well soldered. Naturally the tanks are relatively heavy (tank with 250 liters of fuel weighs 57 pounds).

The fuel tanks are tested for pressure tightness at 0.3 operating pressure; it is advisable not to use easily inflammable fuels. To make the leaks easily discernible the tank seams are given a coating of whitewash.

IV. Riveting with Hollow Rivets

All parts riveted with hollow rivets in the Junkers shops are inaccessible on the inside, both by hand and by auxiliary tools (end caps of wings and ailerons). These rivets made of thin sheet steel tubing are inserted from the outside and riveted with a hollow rivet set which has been patented by Junkers (see Fig. 49).

The method is as follows: the hollow rivet is crimped on the inside by several turns of crimping needle (12) by means of operating lever (10). When depressing arm (2) on the fixed lower arm (1), spindle (7) and needle (12) are raised so that when making a turn with lever (10) the crimped edge of the hollow rivet is pressed tight against the edge of the rivet hole. The riveter is used exclusively for this kind of riveting and has proved satisfactory. All hollow rivets used to have open heads until 1929 when the rivets were closed.

B. Machine Riveting

The use of machine riveting has found increased favor within the last few years in German aircraft construction. The designers are more and more inclined to design the individual structural components with a view to accessibility for riveting machines as well as for more convenient handling while riveting. The use of certain riveting machines hinges on the types of metal construction, hence is characterized by the different machines in use.

I. Riveting with Eccentric Riveting Press

This type is primarily used by the Junkers company (Fig. 50, 51). They utilize 1) the eccentric riveting press made by the Zwickau machine factory A.-G., Niederschlema, Saxony, with a maximum pressure of 6000 kg (3728.4 lb.) of 160 mm² area by

a material strength up to 45 kg/mm²; 2) eccentric riveting press made by the Weingarten machine works, Weingarten, Württemberg, (of about the same size). Both presses handle dural and iron rivets up to 8 mm diameter cold, and up to 14 mm hot. The upper die rests in a chuck which moves up and down in a slide track by means of eccentric blocks. The bottom die is stationary on a bedplate (Fig. 52) and carries the actual heading tool, while the upper chuck holds the dolly. The rivets are inserted from the top leaving the shank hanging down. Then the closing head is "felt" under the top die so that it comes in the half-round recess of the dolly, after which the latter is released by eccentric action (moment tangential wedge coupling), and the bottom die clinches and heads the rivet. The spacing of both dies corresponds to the thickness of the metal sheet. (The stroke is set at slightly less this thickness on account of the spring action.)

Only one man is required to insert the rivet and move the metal sheet along. The press is released by foot lever action. This method has been used quite successfully for riveting the metal covering of wings. The individual sheets, mostly 240 to 300 mm wide and up to 6 m long, are lined up and drilled and tacked to a flat table for easier handling; the rivets are inserted from the top and then, one after the other, clinched and headed. The table on which the metal sheets rest is perfectly flat, metal covered and equipped with wooden rollers 150 mm thick,

spaced from 40 to 60 cm from each other. (See Fig. 52.)

Top and bottom die of the press are interchangeable, depending on the size of the rivet and the kind of riveting, and whether smooth or corrugated metal sheets are being worked. The dies rest in slotted chucks (Fig. 53) which are clamped tight after the top die has been inserted. They are usually bevelled in the direction of feeding (Fig. 54) to enable the riveter to see better when "feeling" the driving head in the die.

For riveting corrugated strips,- Figure 56 shows dimensions,- the dies have a half-round bevel corresponding to the size of the corrugation (Fig. 55). To be sure, top and bottom die have the opposite shape. If, for instance, the top die is convex, the bottom die usually is concave, although this is not absolutely necessary. Drilling of rivet holes is mostly done on the basis of the size of the rivet hole which equals the rivet body diameter plus 0.25 mm. The reason for this is that the rivet must hang absolutely loose in the hole, so that it can be pressed vertically in the bottom die.

In riveting with the eccentric press there always is a possibility that for one reason or another, particularly with thin sheets and small rivet diameters, the rivet may become slanted and present an unworkmanlike job. To avoid this Junkers developed and patented the rivet guide tongs shown in Figure 57. Before and during clinching the rivet is held and guided by the two tong arms. The arms are shaped so that they exert a spring action against the rivet shank (self-clamping and of spring steel),

and gradually move to the side as the clinching progresses by overcoming the spring tension compressing the tongs. Such guide tongs are well known in machine construction but the drawback until now was the difficulty of inserting the rivet shank between the tong arms compressed by spring action, while at the same time it was necessary to have the spring action to prevent the rivet from slipping sideways.

According to the improved Junkers type, the insertion of the rivet between the tong arms is facilitated so that these arms can be easily spread apart by a special guide, and at the same time hold the rivet shank by virtue of the spring action. Rivet body and tong arm both are placed downward at the stationary bottom die; the arms gradually shift enough during driving to make room for the closing head.

The new device is shown in Figure 57. The holding mechanism around the rivet shank consists of two tong arms (1), whose coupling sleeve (2) rests on spring (3) so that the tongs can slide axially with respect to the bottom chuck (4), and move downward when the dolly is let down against the pressure of spring (3). The tong arms, formed as leaf springs, are brought closer to each other through the spring tension during the down movement and press tightly against the rivet shank. In order to hold the tong arms open in their extreme setting and to facilitate the insertion of the rivet shank, the shoulders (5) of the stationary bottom die (6) act in

connection with the side of the tong arms which at that point protrude on the inside. Toward the end of the forming of the closing head, the pressure of the tong arms is reduced and finally released altogether, where the wedge-shaped inside surfaces of the tong arm cheeks (7) lap over the projections (5) of the lower arm and are pressed apart. This method ensures a firm hold on the rivet shank up to the moment the closing head is formed. Another advantage of the axial spring pressure is that the metal sheets are firmly pressed together so that the rivet cannot be crimped between. The danger that the tongs would not return to their neutral end position E-E (in Fig. 58) and in consequence might stretch the rivet hole region (thin sheets are very flexible) was overcome by appropriate shaping of the contact surfaces of the upper die. (See shaded portion, Fig. 58.)

A first condition for satisfactory riveting with the eccentric press is absolute uniformity of size, length and head shape of rivets used. Machine riveting of this kind requires the specified rivet dimensions (see table for dimensions) in every case to ensure that the heads on both sides have the right shape.

It has already been pointed out that rivet shanks for machine riveting must be from 1 to 2 mm longer on the average than for hand riveting, a proof that clinching with the eccentric press is more powerful and more thorough, and shear tests have

proved that a machine-riveted piece is stronger than a hand-riveted piece. (Table 1 dimensions of rivets for longitudinal seams in corrugated metal sheets, showing the longer rivet shanks necessary in riveting press for comparison.)

TABLE I

Sizes of rivets for longitudinal seams of corrugated sheets

Material: Duralumin		Rivet length and use	
Plate thickness	Rivet diameter	Machine riveting	Hand riveting
0.3 + 0.3	2	2DB, 5mm	2DB, 5mm
0.3 + 0.4	2	2DB, 5 "	2DB, 5 "
0.4 + 0.4	2.5	2.5DB, 5mm	2.5DB, 5 "
0.4 + 0.5	2.5	2.5DB, 6 "	2.5DB, 5 "
0.5 + 0.5	2.5	2.5DB, 6 "	2.5DB, 5 "
0.5 + 0.6	2.5	2.5DB, 6 "	2.5DB, 5 "
0.6 + 0.6	2.5	2.5DB, 6 "	2.5DB, 5 "
0.5 + 0.75	2.5	2.5DB, 6 "	2.5DB, 5 "
0.6 + 0.75	3	3DB, 8 "	3DB, 6 "
0.75 + 0.75	3	3DB, 8 "	3DB, 6 "
0.75 + 1.0	3.5	3.5DB, 10"	3.5DB, 8 "
1.0 + 1.0	3.5	3.5DB, 10"	3.5DB, 8 "

Figure 59 depicts several eccentric upper dies (snap die). For rivets up to 3.5 mm diameter the changed die setting worked satisfactorily. With bigger rivets the upper die often showed a crack due to the eccentric loading and excessive deflection by too much eccentricity. Even though the best kind of steel

(matrix steel) was used for the die, this drawback could not be removed.

In Figure 60 we see the Junkers type of eccentric dies for machine riveting, showing the relative figures of permissible dimensions (a) and (b) of rectangular dies for riveting members of hard accessible U sections, and particularly wide closed C sections. Practical shop experiments regarding the accessibility of rivet dies for special shaped subassemblies yielded corresponding numerical values, which showed that satisfactory clinching of the rivet body and heading depends on the deflection and the elastic flexion of the curved top dies (see Fig. 60, a, b, c, d and e). To make extensive use of the eccentric riveting press possible becomes the problem of the designer. One principle in the manufacture of rivet dies is that the rivet head always must be "felt" into the upper die and that the piece to be riveted must follow the lift motion of the die. (See Fig. 60, b and e.)

The compilation further revealed data on the pitch and on the edge distance of the rivets with respect to half-open sections for inside riveting as well as on the effect and size of the arms of the guide tongs. (See Fig. 60, f.) The stroke setting of the machine requires a certain practice in changing from one distance to another when the piece to be riveted has several thicknesses. For that reason automatic devices were developed which regulate the stroke automatically, although

none has been sufficiently proved to warrant permanent installation. Other experiments concerned the riveting of tubular spars on the eccentric press. These, however, have not reached the state of practical application.

II. Riveting with the Titania - Rapid Riveting Machine

This machine, made by the Titania-Works of the Hasse & Co. A.-G., Berlin N 39, is principally used by the Rohrbach metal airplane factory. (Figs. 61-64.) Here the second or closing head is formed by two simultaneous processes, i.e., by a vertical hammer effect of the chisel-like die combined with a rotary motion. The hammer effect of the riveting die (snap head) is accomplished by centrifugal rollers (A) (Fig. 62), arranged at the outer edges of two guide plates and which assume a radial position under the centrifugal force. Die B is slightly depressed by a spring and remains in position of rest as long as striker C is outside of the zone of the centrifugal rollers. The piece to be riveted, which with the rivet head rests on the dolly of the bottom die, is moved by foot lever toward the riveting die together with the lower die which acts as an anvil block. As soon as the rivet shank touches the die the latter, after overcoming the spring tension, is pushed upward so that the striker, during its further upward motion, comes within the zone of the centrifugal rollers. (Position indicated in Fig. 62.) The rollers, whirled outward by the centrifugal force

within the hole limit of the guide plates, now exert a hammer effect on the simultaneously rotating die. The holder-up or anvil is adjustable in height; the guide cylinder which carries the anvil is hollow so that the anvil head can be removed from below.

It should be noted that the arrangement for operating the foot lever must be set correctly. The hammer action of the centrifugal rollers should be as soft and smooth as possible, and should not be continued until striker C reaches its limit position or the centrifugal rollers, whose end position becomes evident by touching the inner hole circle of the guide plates, become unable of further lateral movement and thus are easily damaged. If the striker is too far within the zone of the centrifugal rollers it becomes manifest in the increasing noise which, however, can never be eliminated altogether. Figure 63 shows a die for different head shapes. As a rule the die is chisel-shaped with rounded-off striking edges. The drive shaft on which the guide plates rest has from 670 to 1000 r.p.m., according to the size of the rivet; with 12 centrifugal rollers the machine makes from 8000 to 12000 strikes per minute.

For rivets from 6 to 10 mm body thickness, the machine carries only 4 hammers flexibly arranged on a radial hub (Fig. 64), with 570 to 670 drive shaft r.p.m., or 2000 to 2680 strikes per minute. However, the rivets must be inserted by hand and swelled first to keep them from falling out while the riveting

progresses, because the die head is upside down, and also clinching is not quite as satisfactory with this machine as with the eccentric type, as proved by subsequent tests of single- and double-shear samples - 12 for each test. The difference in shear and tensile strength ranged between 6 to 30% between the hand and the machine riveted samples, which were taken at random, the heads swelled by hand and then finished in the riveting machine. The principal reason for these differences in tensile strength figures was found, upon microscopic investigation, to be due to the decided difference in thickness of the rivet shank diameter after completion of the rivet. It proves that swelling the head by hand is favorable to subsequent clinching of the rivet. Notwithstanding this difference in shank diameter, there still remained a strength difference of from 5 to 15% when converted to the diameter of fracture. The differences in strength, however, have no decisive significance on the strength factors of riveted parts used as basis thus far, for even the minimum possible figures exceed the lower limit of the definite mathematical strength. Then again it should be borne in mind that the workers in machine riveting do not swell the head as much as required in hand riveting.

III. Riveting by Compressed-Air Hammer

This type of riveting is extensively used in iron construction. One reason its introduction into metal airplane construction.

tion has not found more favor was the difficulty of handling the air hammer for small rivets. The striking force, even of the comparatively light hammer at 4 to 7 atm. operating pressure, is so powerful that any slight negligence in handling it might result in a more or less greater damage of the light metal sheet, and in a subsequently greater danger of corrosion. In addition, metal aircraft construction lacks the experience, the riveter himself seems to be averse to handling the air hammer, and, lastly, the noise accompanying its use has not contributed to more universal utilization.

Regarding the use of the air hammers for the different riveting methods in German airplane factories, we mention:

1) In riveting subassemblies accessible from both sides particularly Rohrbach Co., the portable air hammer is used extensively. The manufacture of the separate structural components, some of small size, and the use of heavier rivets (up to 8 mm diameter) favors its application here. All these machines operate with hammer effect; a piston whirls back and forth striking in rapid sequence, blows on the rivet (self-steering compressed-air hammer with free piston) or on a special tool for that purpose (the dolly). As a rule the hammers are light, making easy guiding and handling possible. However, handling the compressed air hammer is not so easy and requires great care in the hands of the riveter, particularly in riveting light metal, such as is used in airplane construction. The

reasons are as follows: after each blow the dolly, driven forward by the piston, bounces off of the riveted piece. If the cylinder lags behind while the tool is moved ahead, it produces what the riveter calls a recoil between both pieces, and is at times quite unpleasant. There also is a danger that the recoiling dolly slides off the rivet head and damages the light metal.

Here it certainly is of general interest to point to a proposed American device* which removes this disagreeable recoil and facilitates the riveting. This shock-damping device (Fig. 65) consists of a tube A of about 25 mm outside diameter with female threads at both ends for nuts B. An iron bar C, 0.25 to 0.30 m long and about 6 mm thick, to which a shock absorber ring D (approximately 15 mm diameter) is welded, passes through tube A. On the inside of A there is likewise a spring E whose tension can be changed by a corresponding shifting of bar C. The latter carries a rubber block F at its free end for damping the shock caused by the hammer blow. The whole shock absorption device can be attached to each hammer cylinder by means of 75 mm clamp A (tool steel) and two 6 mm bolts and nuts. As a rule the distance of striker H is set at about 6 mm, so a 25 mm distance (e) of rubber block F, figured from the front end of the striker piston, imparts sufficient tension to spiral spring E. Figure 65 shows the simplicity of

*Shipbuilding and Shipping Record, Jan. 5, 1928, p. 16.

this shock absorber as well as its easy mounting on any air hammer. The advantages of this device are:

- 1) reduced shocks on the air hammer, which frequently produce fractures in the striker piston;
- 2) easier and safer handling of hammer;
- 3) better workmanship, because the hammer rests more evenly and smoothly on the rivet shank while riveting.

Another worthwhile improvement is the electromechanical air hammer of the Kango Works, U.S.A., as described in The Engineer, Dec. 9, 1927, p. 666. The upper end of the hammer houses a high speed electric motor equipped for operating on A.C. or D.C. The engine shaft carries at one end a gear drive actuating two bevel wheels in opposite directions. The bevel wheels are equipped with opposingly rotating balance weights and are housed in a so-called floating frame. When set in motion the floating frame assumes a definite counterdirectional motion, imparted by the unbalanced forces. This motion is transmitted to striker A. There is a short transmission link in the original hammer cylinder which joins directly on the sleeve B for holding the dipper. As a result the hammer is always ready to use as soon as the motor runs, and the worker feels a continuous shock, whether riveting or not.

Now Figure 66 shows a somewhat improved type of this hammer, which overcomes this disagreeable feature by a different transmitting link C, which is seated and guided in a bushing E,

likewise in housing D which serves to hold sleeve B. In addition, a spring F was inserted between C and B. The arrangement is such that the hammer runs idle until the tool is pressed against the working piece. Regardless of the disadvantages incidental to the use of this type of compressed air hammer, such as difficulties in setting the hammer firmly at the beginning of clinching the rivet shaft because the rivet is loose in the hole so that the head must be swelled first by hand, its use is nevertheless justified in particular for rivets of more than 3 mm diameter. Swelling of the head in light metal being impossible, the riveter must turn the snap die continuously, especially when forming the closing head. To avoid all danger of damaging the metal sheet around the rivet, the dies should be flat bottomed and without sharp edges. Of course, the riveter prefers the latter form of snap heads in order to be able to remove the burring, if the rivet shanks are too long. The force of the blow of the rivet hammer is usually regulated by throttling the compressed air flow. Fewer and more powerful blows are to be preferred to many light blows, because light blows may induce strong local hardening of the rivet, forcing the head to snap off. According to the experiences gained by the Rohrbach airplane company with the compressed air hammers, its more universal use is in every way justified.

2) Riveting subassemblies accessible from one side only, i.e., primarily in the Junkers airplane shops, has found more extensive

use within the last year, chiefly in riveting tubular spars. The assertions made against its adoption were many, but shop tests have proved that none of the reasons advanced were sound or substantiated.

In so-called English riveting the use of compressed air hammers is particularly advantageous because the snap die of the air hammer sits directly on the rivet head and the second head is formed by the bucking-up tool inside. There is less danger of the die slipping off the rivet head, the work of the riveter in continuously pressing down on the air hammer is lessened, because the snap die always sits firmly on the rivet head, and there is no progressive forward movement of the hammer as the clinching increases.

Tests have shown that an experienced riveter soon gets the "feel" for the correct number of blows and the exact time required, although Junkers uses an automatic time release and air closing device with foot lever operation. It has been ascertained that the number of blows in hand riveting, even with identical hammer weight, size of rivet and length of shank, fluctuate between 8 to 18 blows per rivet, hence there cannot be any serious objections against a sweeping introduction of compressed air riveting.

It was found that a working pressure of 6 atm. in the pressure tank and a 2 second riveting period were profitable for 3 mm diameter rivets. Junkers uses the Boehler compressed

air hammer type 15 to 18. The output of the stationary compressor is 4.2 m³ intake pressure/minute; a valve in the intake regulates the pressure. Aside from the compressed air tools with reciprocal movement the Junkers company also uses some with exclusive pressure action in one direction only. With these tools it is solely a concern of the dolly, such as is used for riveting ball joints. The dolly has one or more radial pistons perpendicular to the longitudinal axis of the tool, which, under pressure, are forced against the opposite side of the rivet hole inside of the tubing. The actual bucking-up tool is pressed against the rivet head under high pressure, and the use of compressed air dollies presents a decided improvement and time saving in contrast to the hand dollies outlined under II a, etc. As far as concerns their introduction into metal airplane construction we have merely begun, and further progress will undoubtedly be made through the lower costs of riveting in metal aircraft construction. This is evidenced by the forward steps in American experiments. There from 3000 to 4000 rivets have been driven in an eight hour shift with pneumatic riveters, while the best time for hand riveting was from 500 to 600 rivets for the same time period.

IV. Riveting with Riveting Tongs

We mention here (Fig. 67) the riveting tongs used by the Junkers company in subassemblies with rivet rows only a slight distance from the edge (up to 50 mm). The method of operation

can be seen from the sketch; it is a substitute for the eccentric press, used for rivets up to 3 mm diameter.

C. Automatic Riveting

The trend toward further development of known methods of riveting and riveting tools was from hand riveting to automatic riveting by way of machine riveting. The main object was saving in time and energy. The problem has received active furtherance by the Junkers company, since it undertook airplane construction on a strictly production basis. It became a question of further development in machine riveting with the eccentric press, to be combined later with a semiautomatic riveter and special devices for drilling rivet holes.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

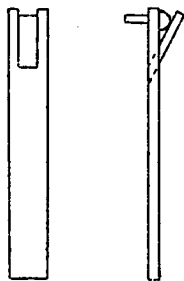


Fig.1 Rivet inserter.

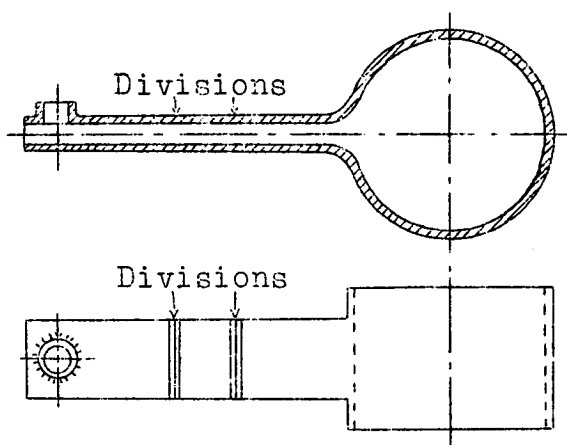


Fig.2 Drill pattern

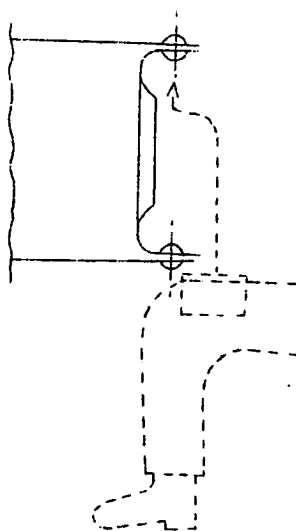
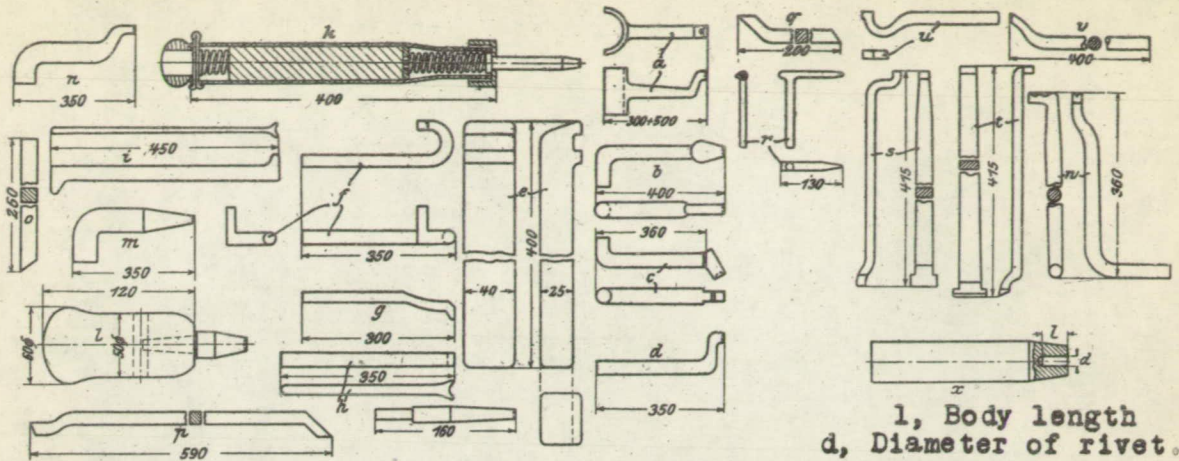


Fig.8 Riveting with dolly and knee plate.



- a, Dolly with knee plate
b,c,d, Dolly bar
e,f, Dolly for radiators
g,h,i, Dolly for floats
k, Elastic dolly
l, Heavy dolly with interchangeable head for inside riveting of low pieces.

- m,n, Dolly bars
o,p,q,r,s,t, Dolly for wings
u, Dolly bar for assembly
v, Dolly bar for tapered ends, (assembly)
w, Dolly bar for junctions, (assembly)
x, Riveting set.

Fig.3 Various dolly bars (Junkers).

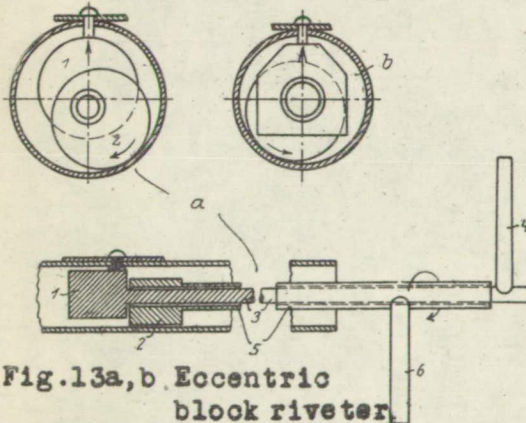


Fig.13a,b Eccentric block riveter with different block shapes.

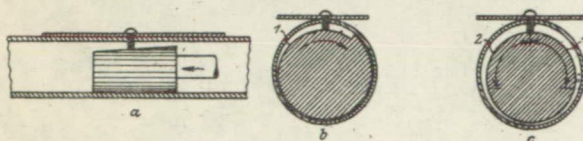


Fig.14a,b,c Rotating eccentric blocks with special block shapes.

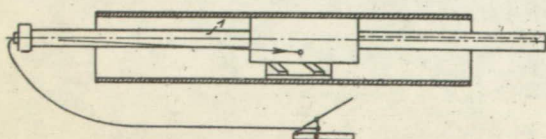
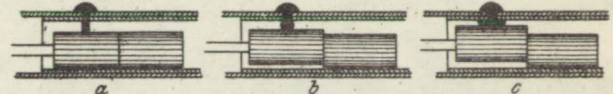
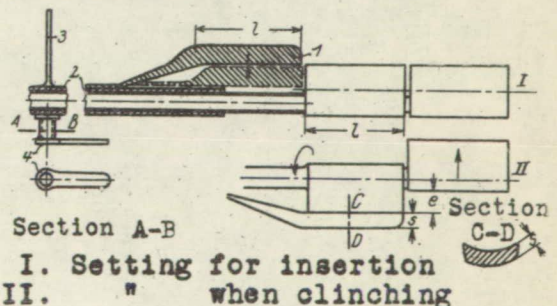


Fig.34 Riveter with Bowden cable and guide tube.



- a, Eccentric with stationary block below inserted rivet
b, Half finished rivet.
c,d, Correct driven rivet.

Fig.17a,b,c,d Regulations and examples for correct handling of rotating eccentric blocks.



Section A-B

- I. Setting for insertion
II. " when clinching

Fig.18 Eccentric block with double stroke.



Fig.35 Two-block riveter with spring and sliding wedges.

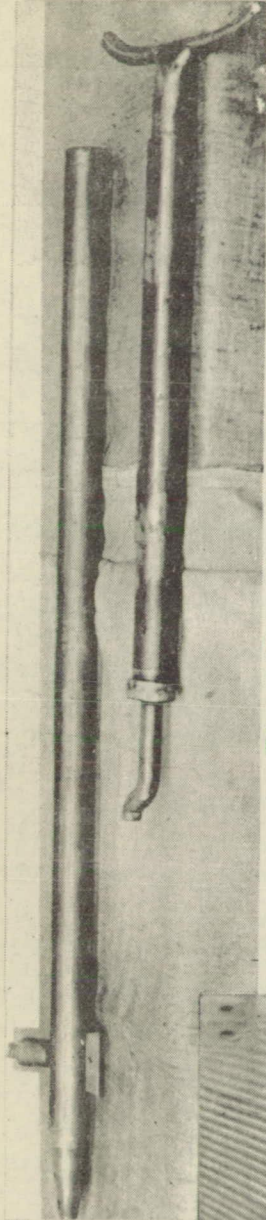


Fig.4 Elastic dolly bars.

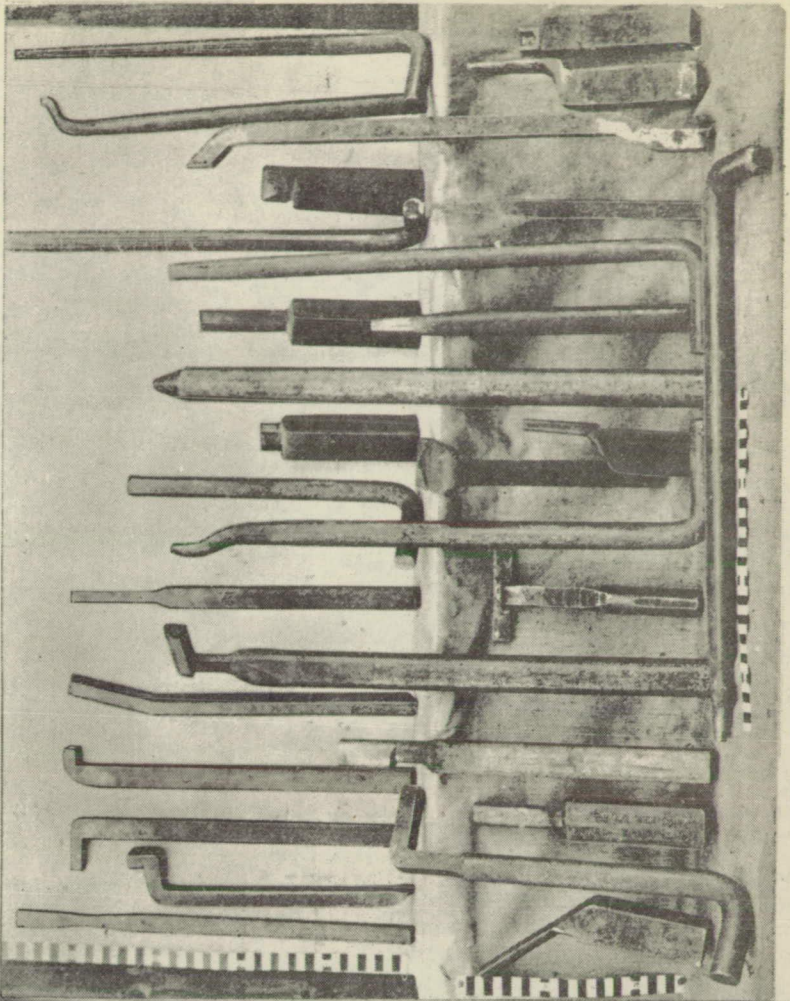


Fig.5 Various dolly bars (Junkers Co.).

Fig.6 Hand
riveting
of fuselage
(Junkers).



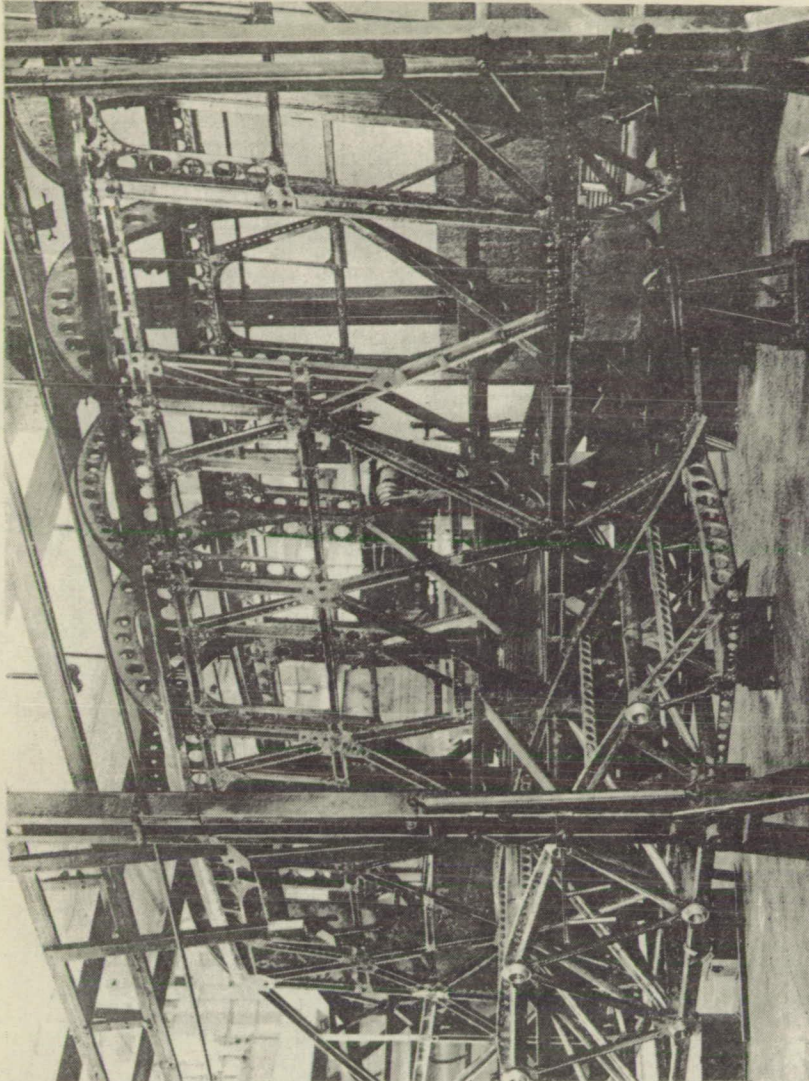


Fig. 7 Fuselage of Junkers G-24

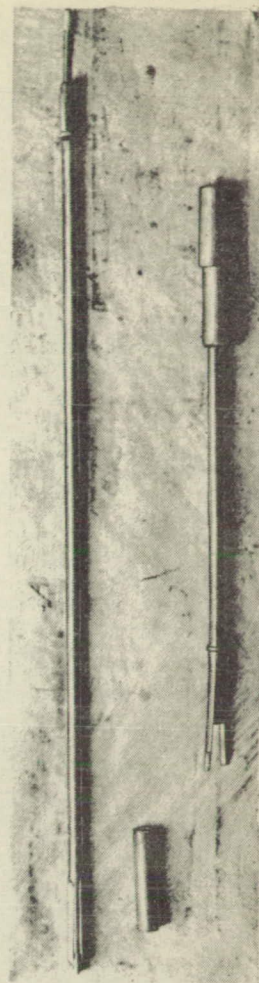


Fig. 12 Rotating eccentric block riveter

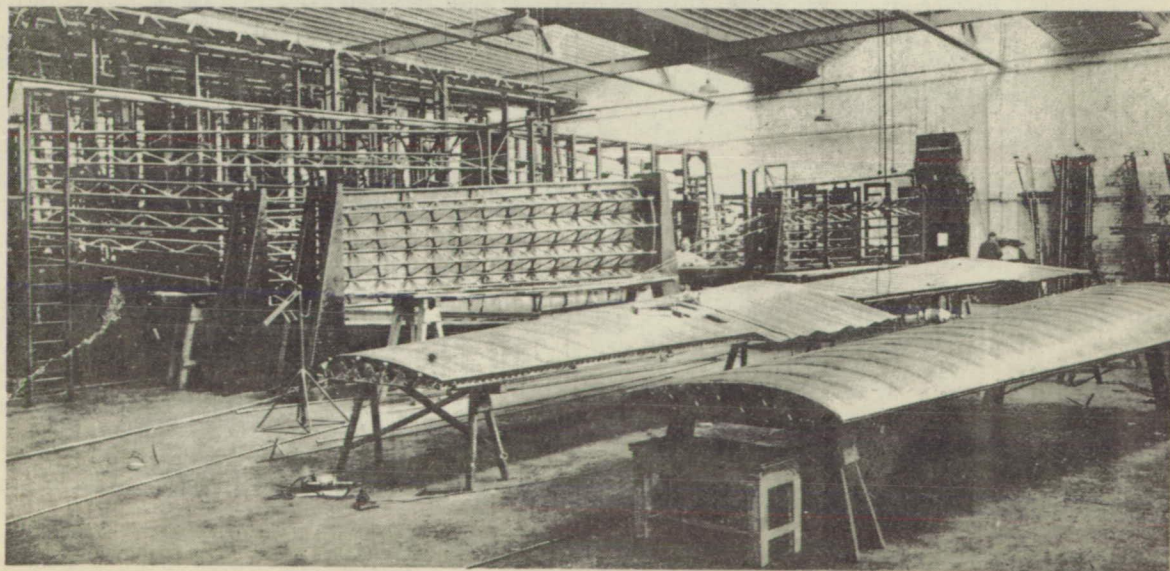


Fig. 15 Wing assembly and riveting (Junkers).

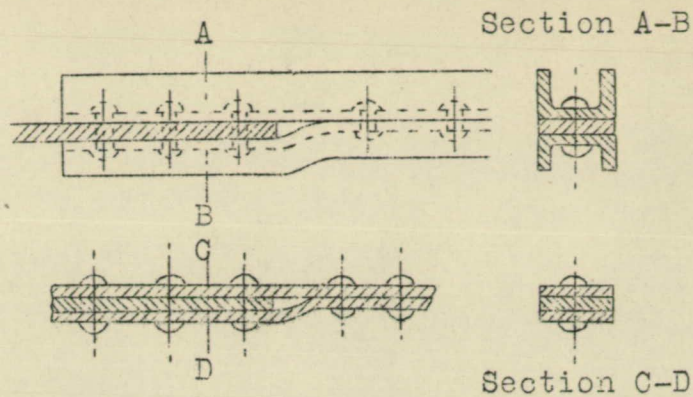


Fig. 9 Longerons with bent section.

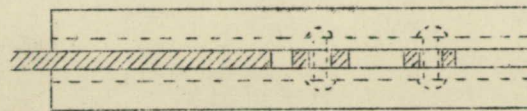
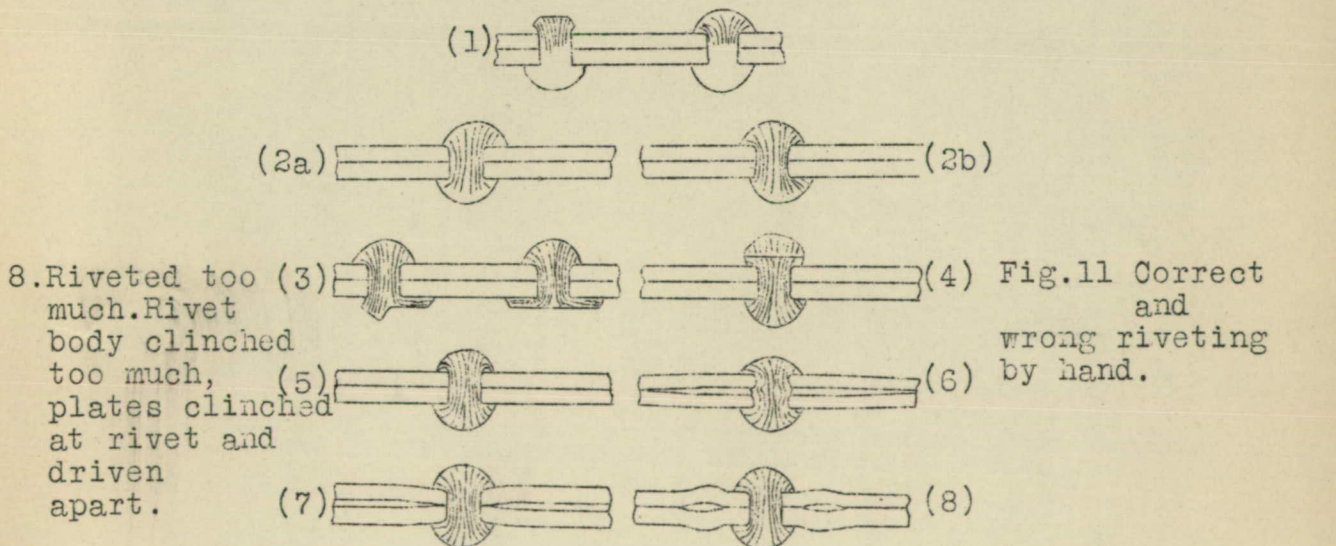


Fig. 10 Longerons with spacing disks.



1. Correct riveting in two operations.
- 2a. Dolly position correct, rivet driven wrong.
- 2b. Rivet driven correct, dolly at slant.
3. Rivet flat on one side, or dolly held flat.
4. Rivet driven correct, closing head to high, body of rivet to long.
5. " " " , body of rivet to short consequently closing head shaped too much with snap die.
6. Rivet not pulled tight, clinches between plates, closing-head to flat.
7. Rivet tight, plates bulged on account of poor fit.

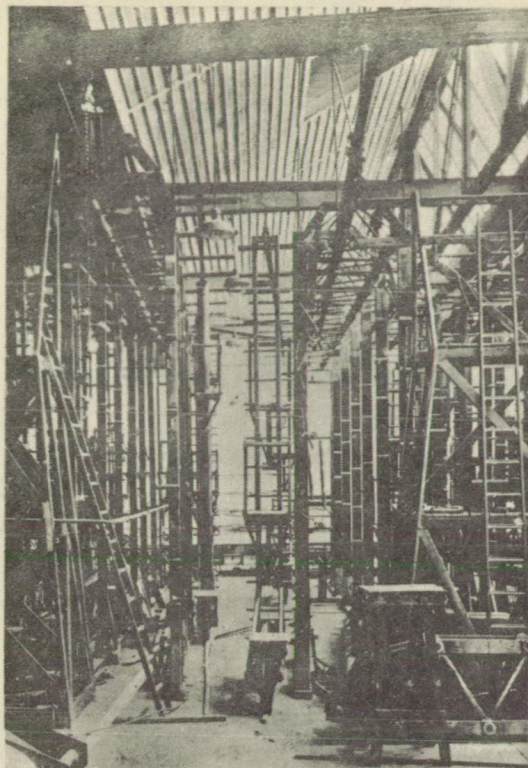


Fig. 23

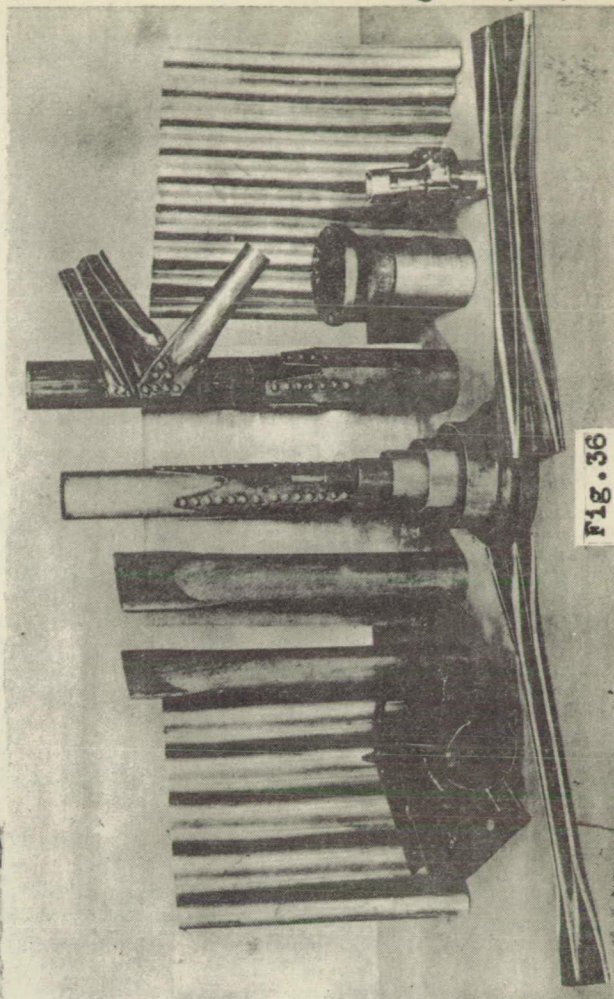


Fig. 36

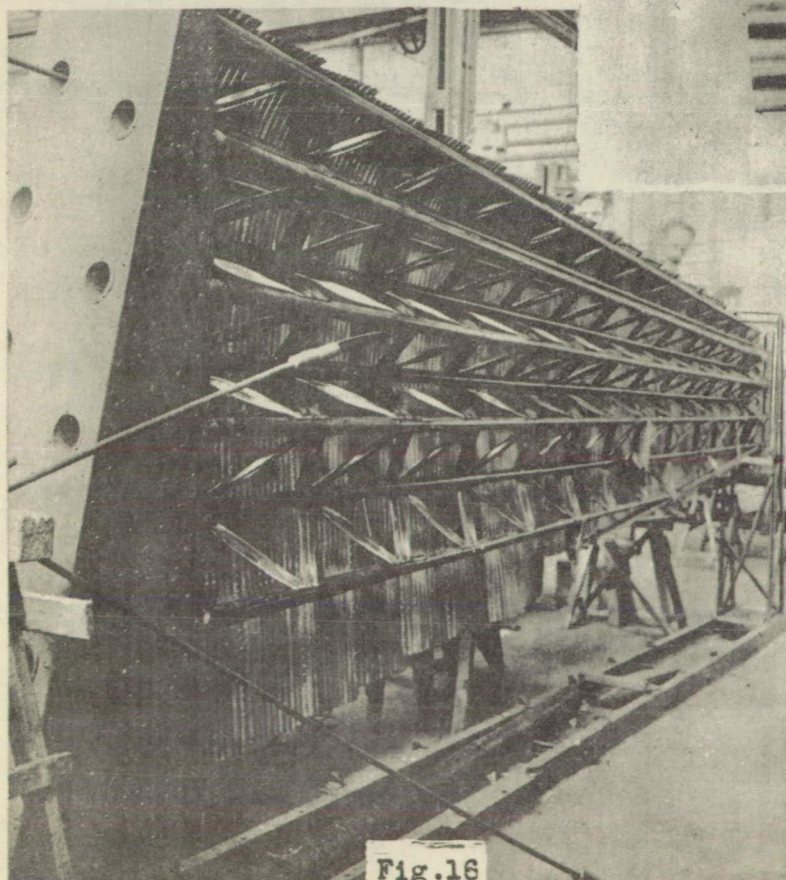
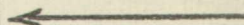


Fig. 16

Fig. 36 Spar junction,
Z strut, tubular
joint, tubular splice,
(Junkers).

Fig. 23 Upper left.
Portable
scaffolding for rivet-
ing on G-24 wings,
(Junkers).

Fig. 16 Riveting on
F-13 Junkers
wing.



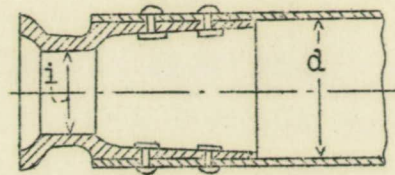


Fig. 19 Riveting ball joints.

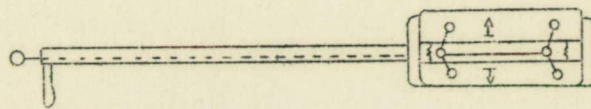


Fig. 20 Two-block riveter with lever

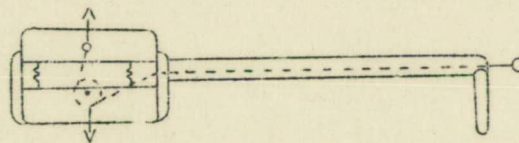


Fig. 21 Double block riveter with pulley.

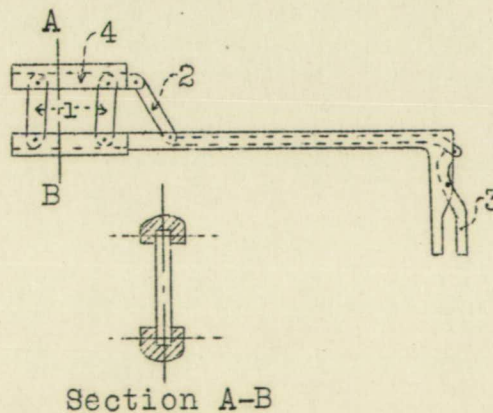


Fig. 22 Sliding eccentric with tongs.

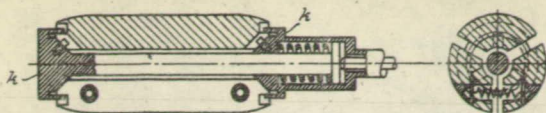


Fig. 26 Three-block riveter with spring-supported cones.

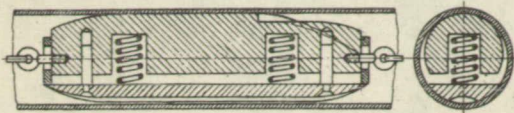


Fig. 28 Two-block riveter with guide surface.

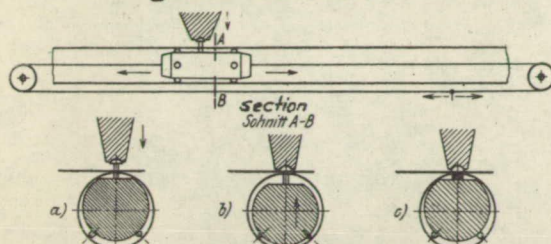


Fig. 30 Inside riveting with spring buttons.

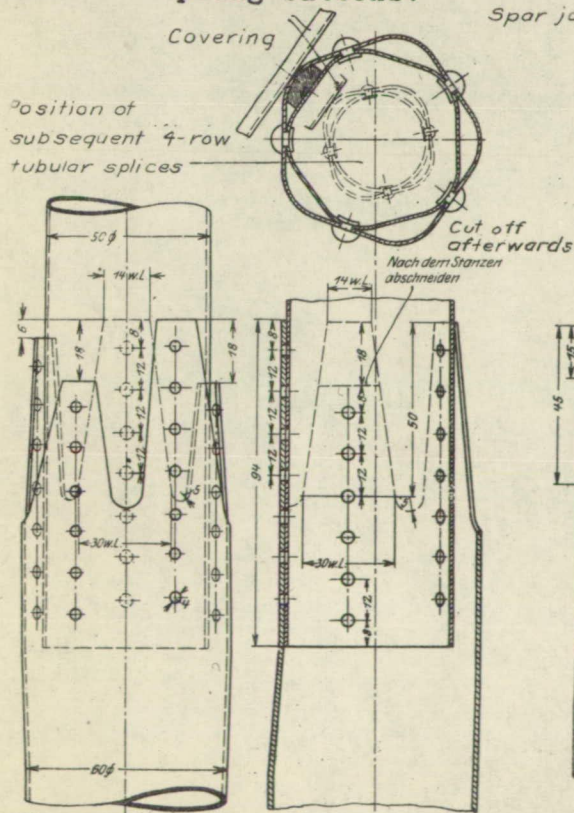


Fig. 32, 33 Various tubular spar joints (Junkers).

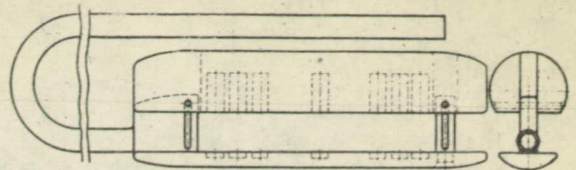


Fig. 29 Two-block riveter with guide surface and guide tube.

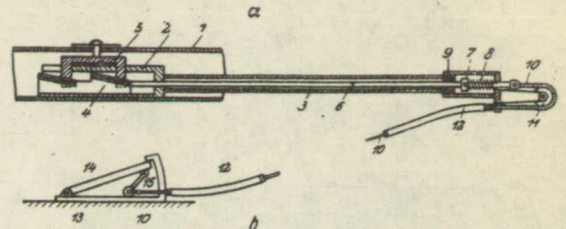


Fig. 31a, b, Bucking up tool with different types of foot operation.

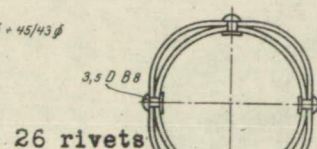


Fig. 27 Three-block riveter with spiral blocks.

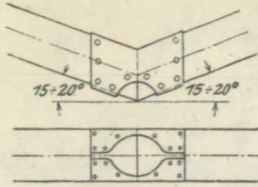


Fig. 34 Obtuse angled tubular joint (Junkers)

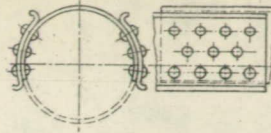


Fig. 39 Riveting of tube ends.

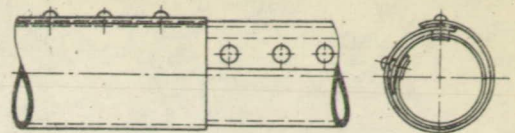


Fig. 45 Splicing of tubing made by riveting open plates. (Exaggerated representation)

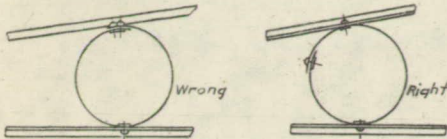


Fig. 46 Right and wrong riveting of longerons with riveted tubular spars.

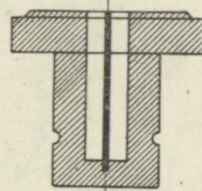
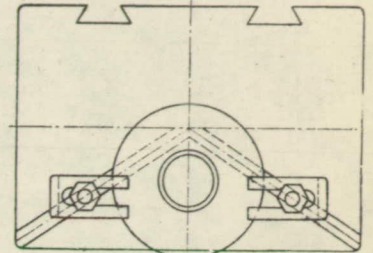


Fig. 53 Die chuck



Bolts slide horizontal in diagonal and longitudinal grooves

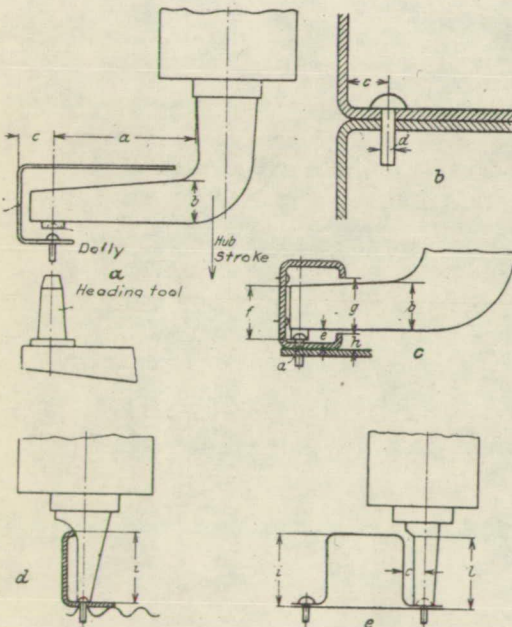


Abb. 54 und 55. Besondere Formen

Figs. 54, 55 Special upper die shapes of eccentric press.

Fig. 52 Table of eccentric press.

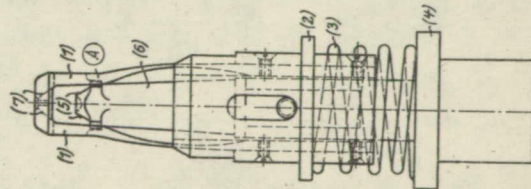


Fig. 57 Guide for tongs for eccentric press, (Junkers type)

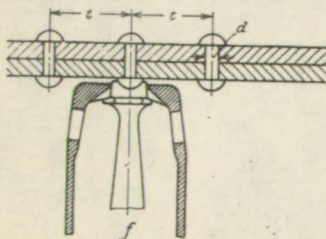


Fig. 60 a, b, c, d, e, f Principles of machine riveting with eccentric dies.

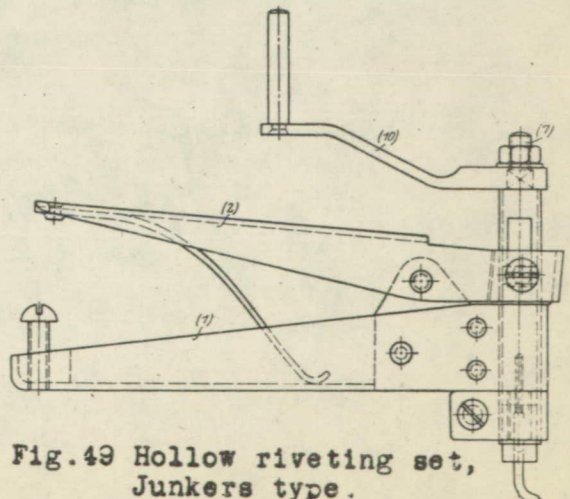


Fig. 49 Hollow riveting set, Junkers type.

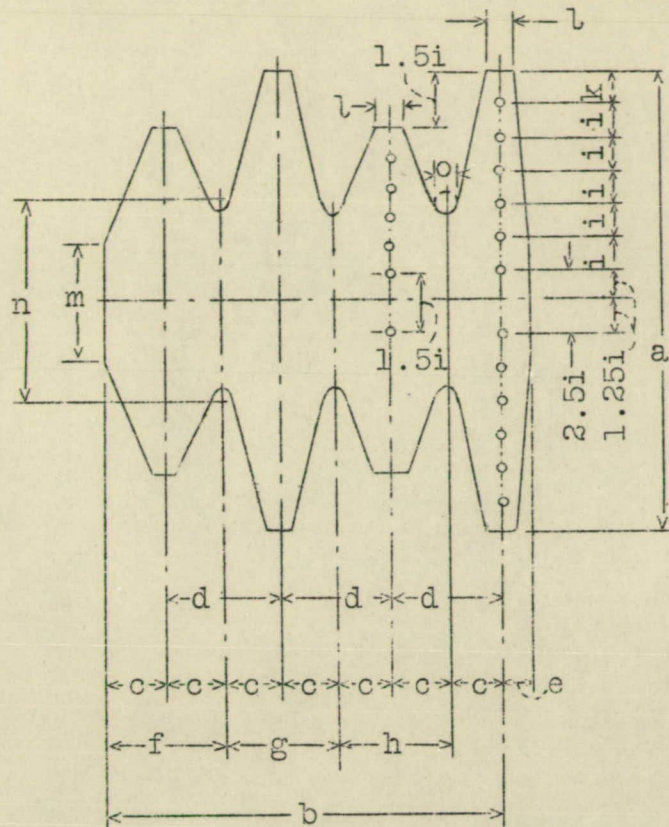


Fig.35 Dimensions and shape of butt plates.

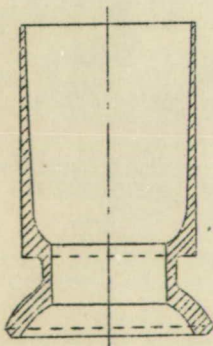
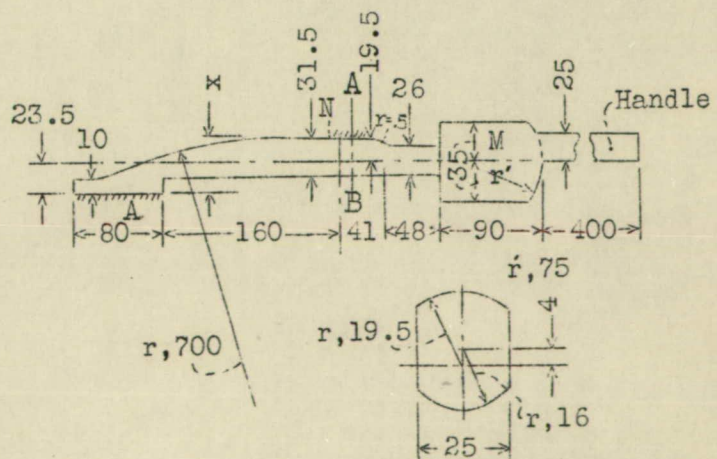


Fig.40 Part of
ball joint.
(New Junkers type)



Section A-B
Fig.41 Dolly for riveting ball sockets
on Junkers F 13, dolly M
outside.

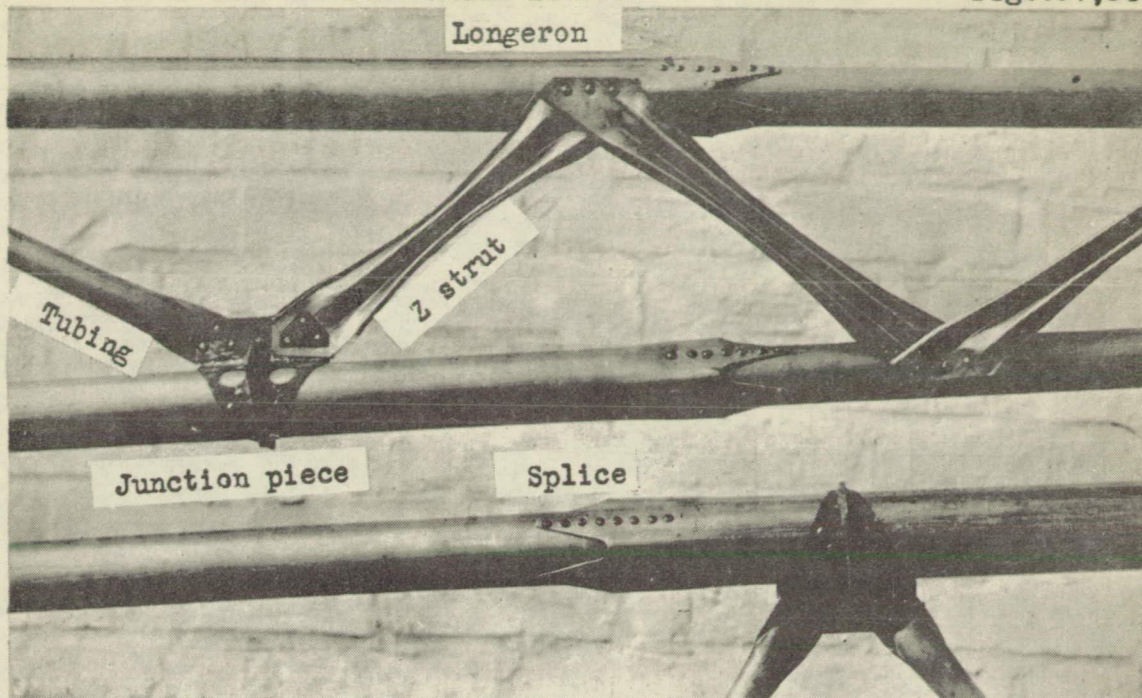


Fig.37 Tubular splice and riveting of Z struts, (1916 Junkers method)

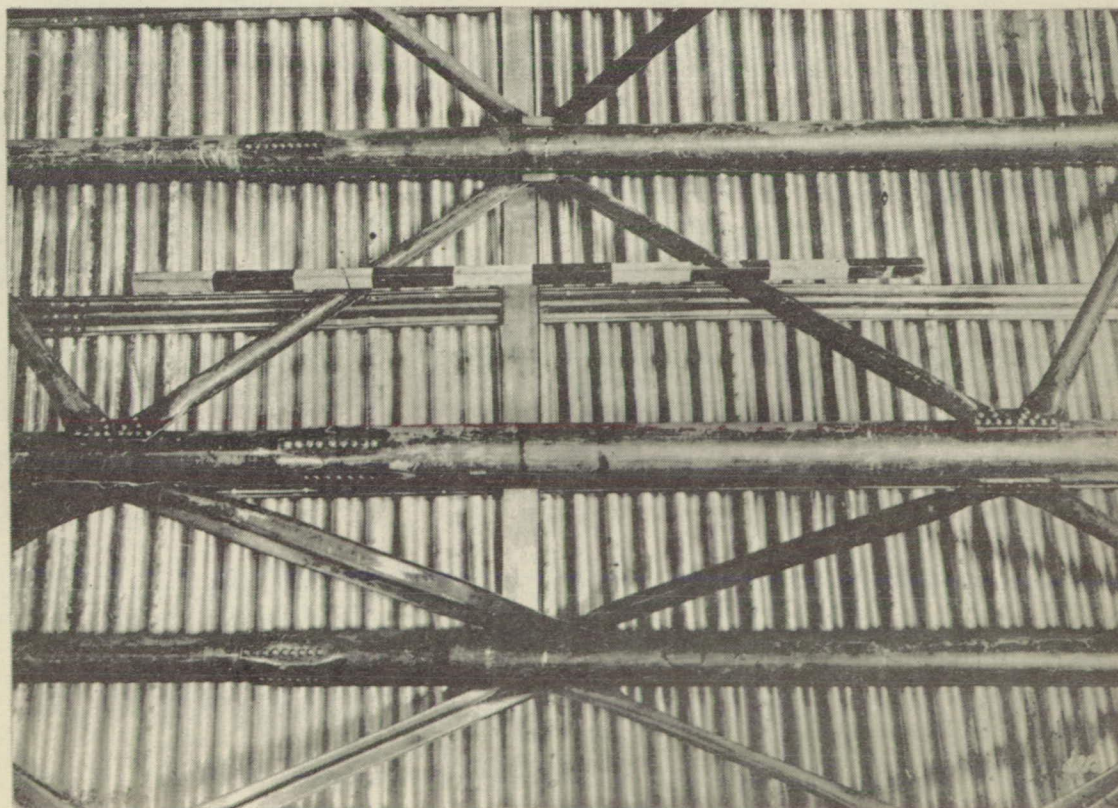


Fig.38 Tubular splice and riveting of Z struts on G-24 wing, (1925 Junkers method)

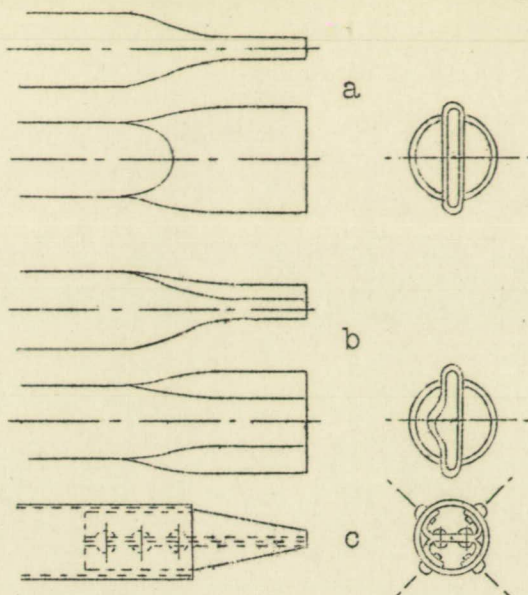


Fig.42 Various forms of flattened tube ends.

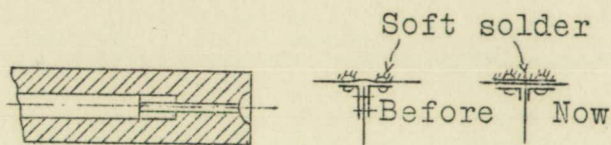


Fig.47 Heading tool applicable as riveter. Fig.48 Caulking tank rivets.

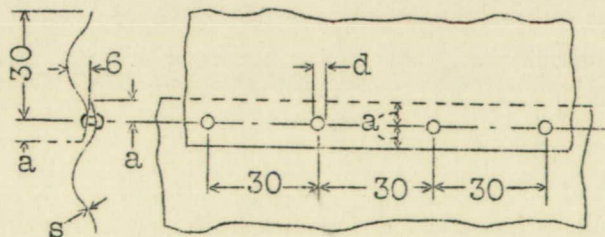


Fig.56 Longitudinal seam riveting for corrugated plates.

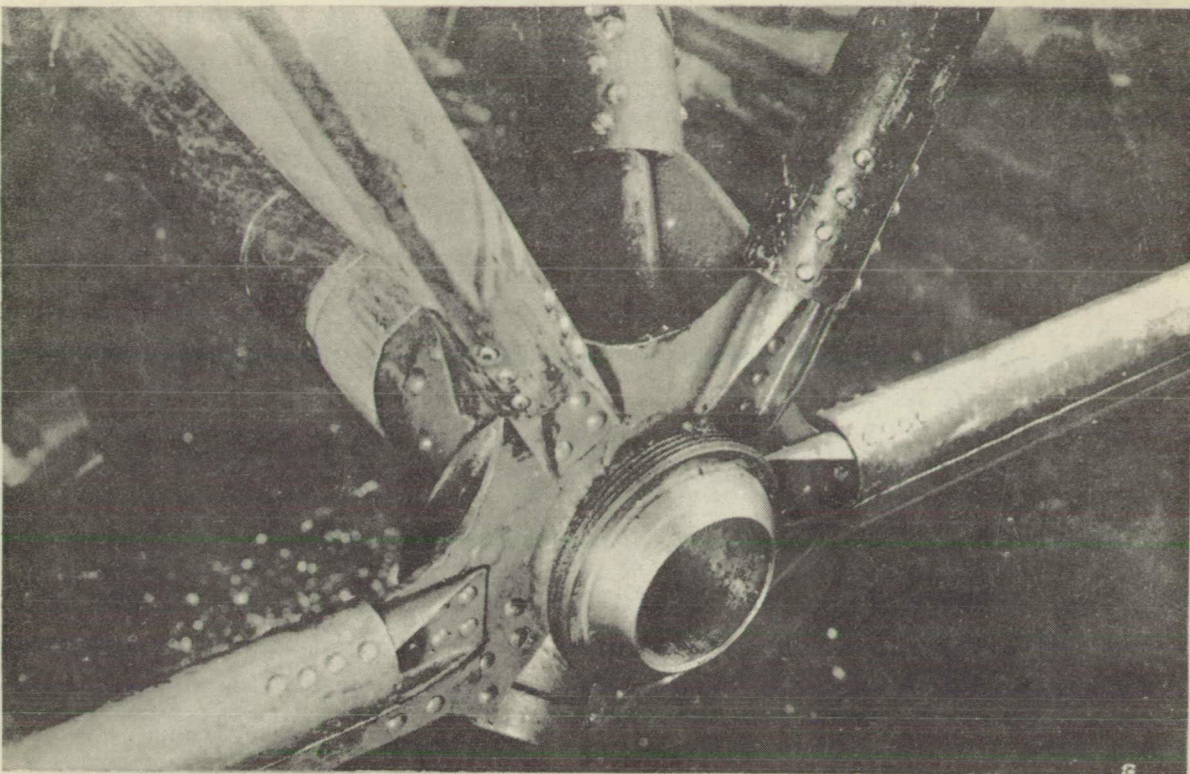


Fig.43 Riveted junction plates of Junkers G-24 wing with ball joint.

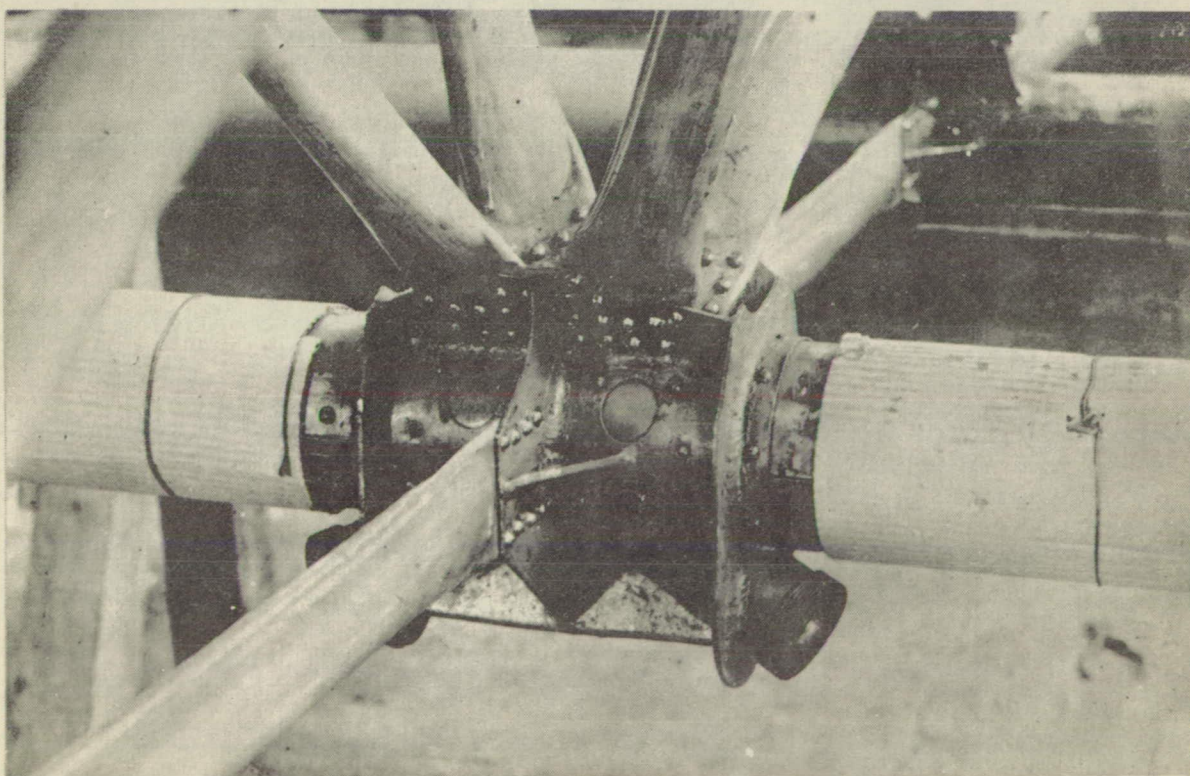


Fig.44 Riveted junction plate with landing gear strut attachment on Junkers G-31 wing.

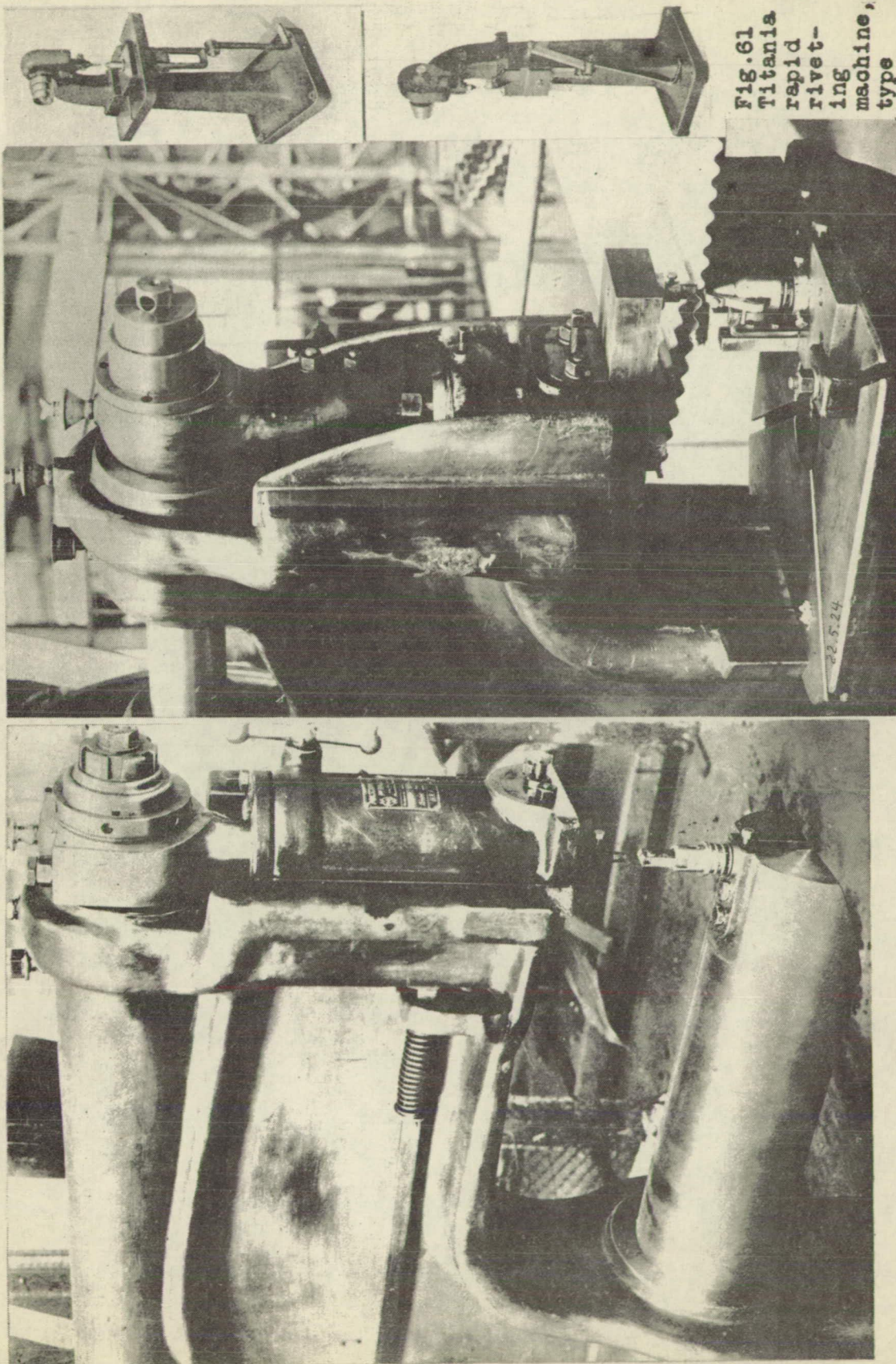


Fig.50 Eccentric press with rivet inserting tongs.

Fig.51 Riveting corrugated strips with eccentric press.

Fig.61
Titania
rapid
rivet-
ing
machine,
type
N1-N3.

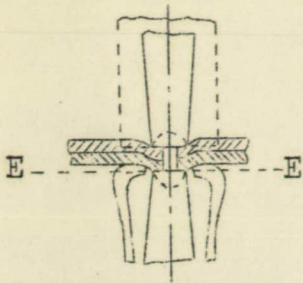


Fig. 58 Deformation of
plate riveted
with eccentric press

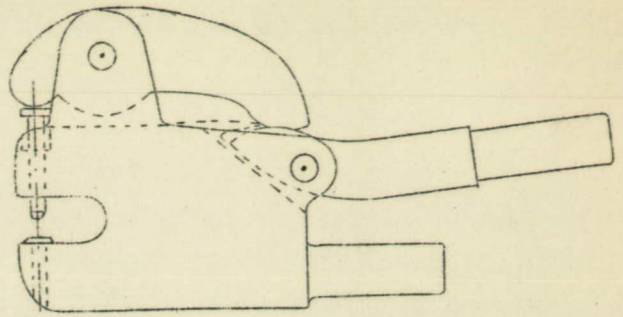


Fig. 67 Riveting tongs.

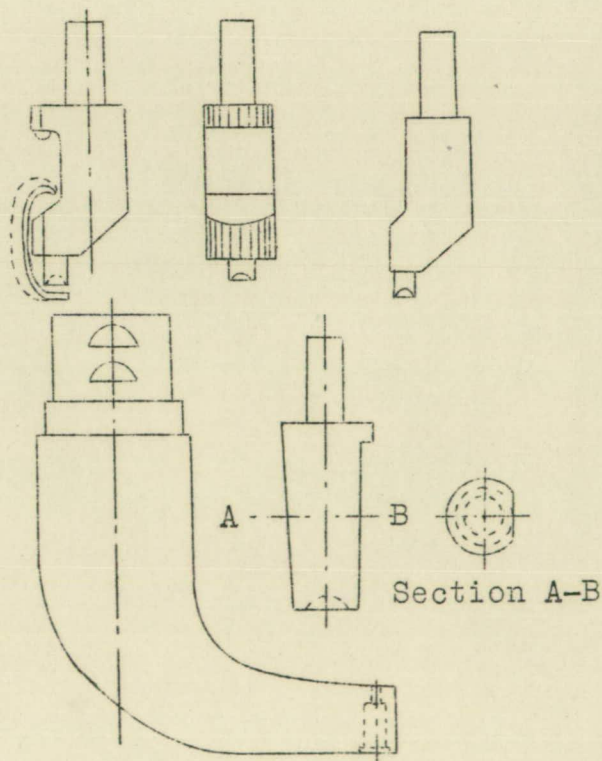


Fig. 59 Various eccentric dies for eccentric press.

(2) For half round heads.

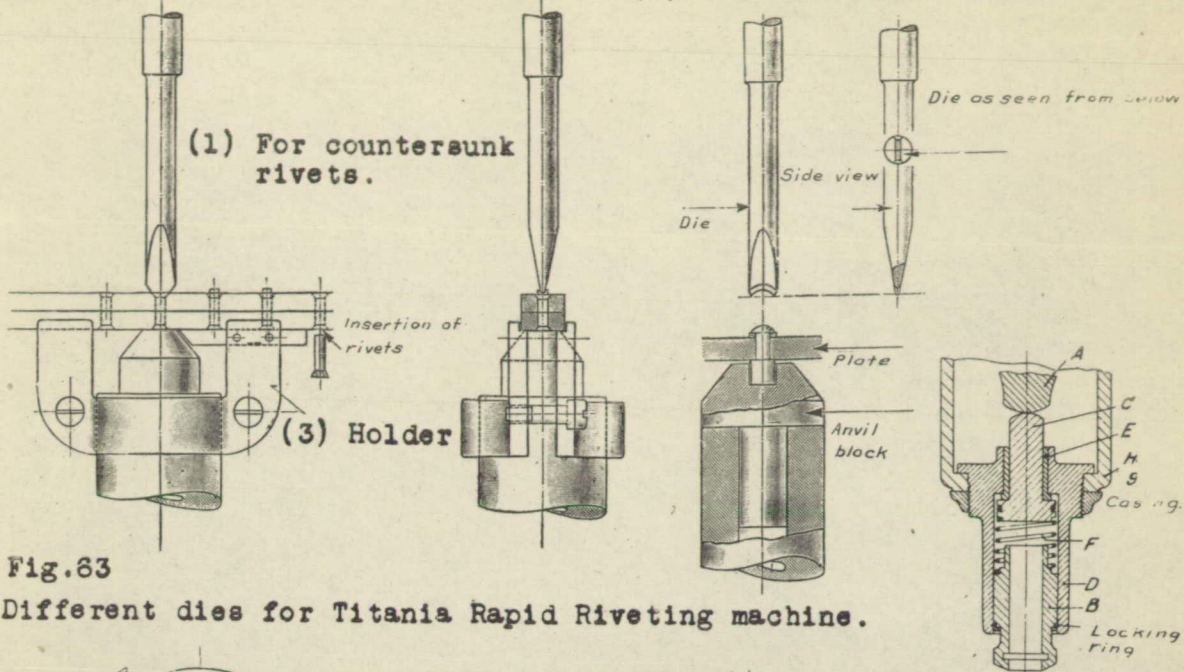


Fig.63

Different dies for Titania Rapid Riveting machine.

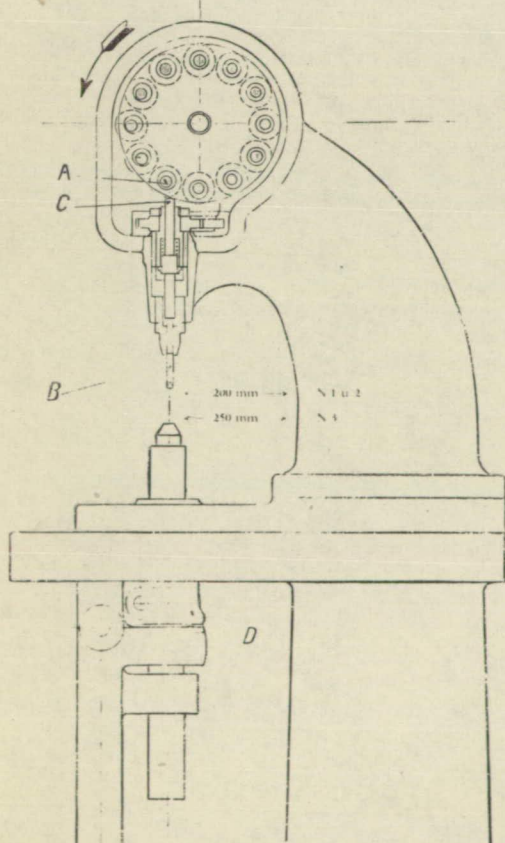


Fig.62 Titania Rapid Riveter type N1 and N3. According to manufacturer, the new types will have 10 centrifugal rollers instead of twelve.

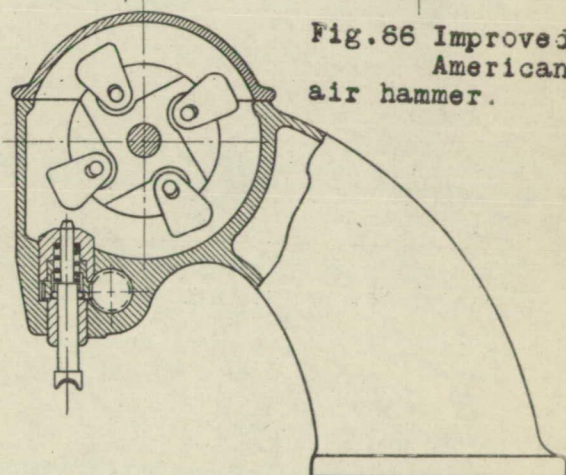


Fig.66 Improved American air hammer.

Fig.64 Titania Riveter N6, discontinued type.

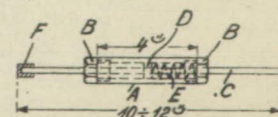
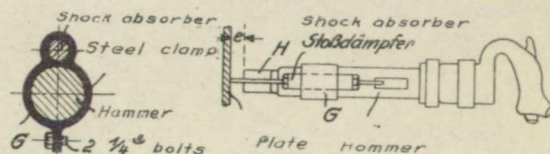


Fig.65 Special shock absorption device on compressed air hammer.